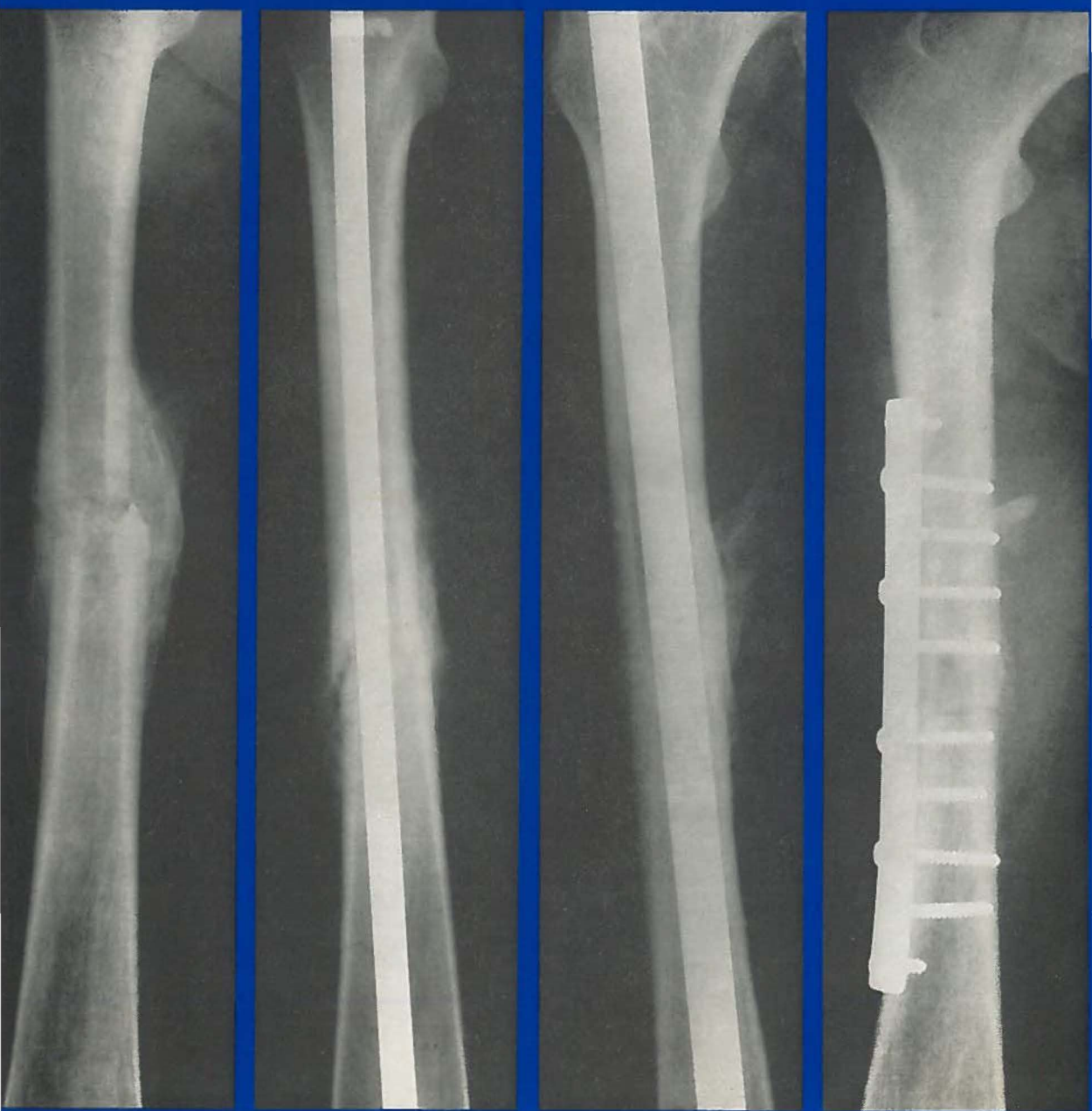
FEMORAL SHAFT FRACTURES IN ADULTS

G.KOOTSTRA



Femoral Shaft Fractures in Adults

Stellingen

1. Een spongiosaplastiek, 6 à 8 weken na een à chaud uitgevoerde osteosynthese van een femurschachtfractuur, is een logisch vervolg op de begonnen behandeling.

2. Het open of gesloten zijn van een femurschachtfractuur is geen goede maat voor de ernst van de beschadiging van de omringende weefsels; een betere parameter is de mate van versplintering van het bot.

3. Wanneer bij een bejaarde patiënt na osteosynthese van een femurschachtfractuur een diepe infectie optreedt, dient een bovenbeensamputatie als levensreddende ingreep te worden overwogen.

4. Het experimentele werk van Hubbard, waarbij de intramedullaire pen in het distale fragment van een spiraalvormige femurschachtfractuur met cement wordt verankerd, verdient met het oog op klinische toepassing, nadere uitwerking. Hubbard, M. J. S., Acta Orth, Scand., 44 : 55, 1973.

5. De criteria voor hersendood hoeven niet de volledige afwezigheid van reflexen in te houden. Ivan, L. P., Neurology, 23 : 650, 1973.

6. Het ziektebeloop van een langdurig zieke, in slechte algemene toestand geraakte patiënt, waarvoor ziekenhuisopname niet is te realiseren, kan na spoedopname in een verpleegtehuis een verrassende wending ten goede nemen. Het opnamebeleid van een verpleegtehuis dient ook hierop te zijn afgestemd.

7. Iedere verkeersdode dient te worden geobduceerd.

8. Bij drugspuiters en bij patiënten, bij wie een klepprothese is geïmplanteerd, moet bij persisterende temperatuurverhoging rekening worden gehouden met endocarditis.
   Dit heeft diagnostische en therapeutische consequenties. Kaye, D., Med. Clin. N. Amer., 57 : 941, 1973.

9. Oligurie bij een patiënt, die een onderhoudsdosering corticosteroïden gebruikt, kan het enige symptoom zijn van algemene peritonitis.

10. Bij een comateuze ongevalspatiënt met meerdere letsels dient ter uitsluiting van een letsel in de buikholte een abdominale paracentese en spoeling te worden verricht.

11. De ontwikkeling van de zeilsport op het Lauwersmeer is gediend met de aanleg van een bevaarbare verbinding tussen de Zoutkamperslenk en de slenk naar Dokkumernieuwezijlen.

12. Met de invoering van een autovrije zondag dient het Arabische paard te worden gekruist met het Groningse trekpaard.

Stellingen behorende bij het proefschrift getiteld:
"Femoral Shaft Fractures in Adults", G. Kootstra.

RIJKSUNIVERSITEIT TE GRONINGEN

Femoral Shaft Fractures in Adults

A study of 329 consecutive cases with a statistical analysis of different methods of treatment

Proefschrift

ter verkrijging van het doctoraat in de Geneeskunde
aan de Rijksuniversiteit te Groningen
op gezag van de Rector Magnificus
Dr. A. Wattel
in het openbaar te verdedigen op
woensdag 21 november 1973
des namiddags te 4 uur

door

Gauke Kootstra

geboren te Scheemda

VAN GORCUM & COMP. B.V. — ASSEN 1973

PROMOTOR: PROF. DR. P. J. KUIJJER
COREFERENT: DRS. B. BINNENDIJK

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Aan Mariëtte

Ten Geleide

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Professor Dr. M. J. Kingma ben ik dank verschuldigd voor de nuttige suggesties, gedaan ten tijde van de voorbereiding van het manuscript.

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Mejuffrouw J. T. ten Hove heeft vaardig het manuscript tot type-script omgewerkt.

De Heer Th. van Winsen heeft met grote nauwgezetheid de Engelse vertaling verzorgd.

De illustraties zijn vervaardigd door de Heer D. Elzinga, de Heer M. J. Martens, de Heer A. Huiser en de medewerkers van de Centrale Fotodienst.

Contents

Chapter I
Introduction

I.1. INTRODUCTION

The femoral shaft is an important component of the suspensory and locomotor apparatus of the human body. An injury of the thigh which involves a femoral shaft fracture precludes locomotion. The victim becomes dependent on others; he becomes a patient.

The patient runs a number of risks: shock, fat embolism and infection. Long-term dangers are those inherent to prolonged immobilization in conservative treatment. Operative treatment also entails risks. For some considerable time the patient has to resign himself to inability to work, and perhaps to a certain degree of permanent disability – a social complication which has its inevitable psychological effects as well.

It is therefore understandable that the treatment of patients with a femoral shaft fracture has always been a focus of interest.

Primitive peoples knew that immobilization was necessary for fracture healing; but their methods of reduction, if used at all, were very imperfect. Consequently a femoral shaft fracture often healed with substantial shortening. The finding of a shorthened femur of a patient who lived at the beginning of our Christian era (fig. 1), is an example of this fact.

Four centuries earlier Hippocrates (about 400 B.C.) had been the first to write an exhaustive scientific treatise on fractures in which all elements of modern fracture management are recognizable (Van Loon 1935). Hippocrates emphasized the importance of maintaining adequate extension when dealing with femoral shaft fractures, 'for it is a disgrace and a pity to shorten the femur'. Hippocrates preferred manual reduction on the day of the accident or the next. If this was omitted, then he advised to wait one week before an attempt at reduction should be made.

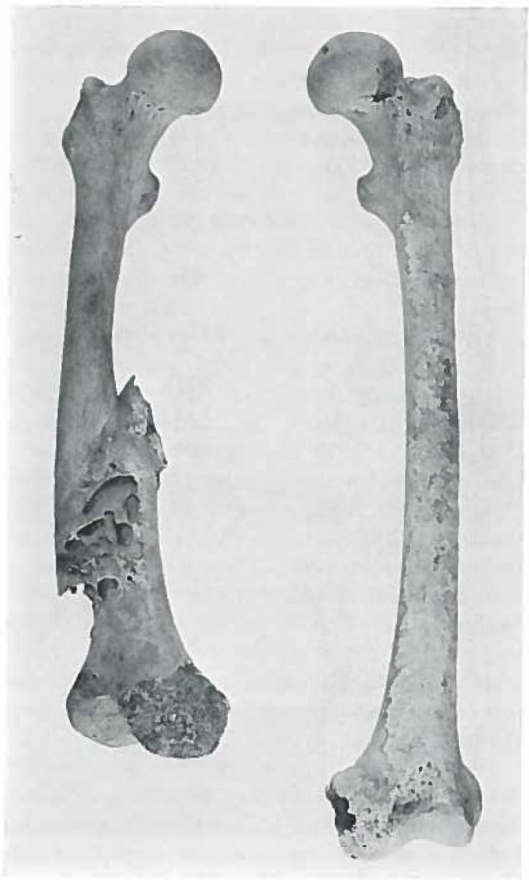

Figure 1. Femurs of a human skeleton excavated from the mound 'Luttie Lollum' mear Franeker (Frisian Museum, Leeuwarden, Netherlands). The site is marked on the map in figure 4. Estimated age: 2000 years. The right femur shows a united femoral shaft fracture with 6 cm shortening, 30° exorotation and a few degrees of varus angulation.

Hippocrates did not hesitate to perform an open reduction either (Van Loon 1935).

Through the centuries, reduction and its maintenance have continued to pose problems, as indicated by the many methods adopted in the course of time. Immobilization was achieved with aid of clay bandages, splints and frames.

Many Dutchmen have made their contributions to fracture management. Professor Hendriksz in Groningen was among the first (1814) to re-introduce plaster of Paris in the treatment of fractures (Van Loon 1935). Mathijsen made a radical improvement by introducing the plaster bandage in 1852 (Spoelstra 1970). The principle of the swinging extension bandage was evolved by Metz (1904) and later received wider acceptance in the use of the Balkan frame and in Russell traction (Kingma and Rogge 1973).

Traction on the skeleton was introduced by Steinmann (1907) and modified by Kirschner (1927) with his wire and stirrup (Dencker 1963).

L. Böhler (1937, 1957) did pioneer work with systematic fracture management, and conservative treatment in particular flourished under his direction.

Operative treatment started with the introduction of asepsis in the beginning of the 20th century. Lane used plates and screws (1905). Lambotte introduced the 'fixateur externe' (in 1907) and in 1918 Hey Groves made use of a massive nail in the medullary cavity (Watson-Jones 1950). The technique of intramedullary fixation was further perfected by Küntscher and re-introduced in 1940. The extent of application was considerably enlarged when he introduced a technique to ream the medullary cavity (Küntscher 1959, 1967). In the treatment of femoral shaft fractures, Küntscher nail osteosynthesis has become a technique which is employed on a worldwide scale (Roberts 1962).

In the Sixties, a group of Swiss surgeons and engineers (Association for the Study of Osteosynthesis) developed osteosynthesis techniques which ensure so high a degree of stability that functional restoration of the limb is achieved early in the course of treatment.

These so-called A.O.-osteosynthesis techniques consist of intramedullary fixation as well as fixation by means of screws and plates, with further enhancement of the stability of the osteosynthesis by interfragmentary compression (Müller et al. 1965).

Several Dutch investigators have published papers on femoral shaft fractures. In the Twenties, Van Eden (1925) reported on permanent disability following femoral shaft fracture, noting that an average of 25% of these patients were granted permanent compensation. Tordoir (1945) and Moeys (1952) did important work on Küntscher nail osteosynthesis. Binnendijk and Ponsen (1969) focused attention on A.O.-compression plate osteosynthesis of femoral shaft fractures. Verbeek and Kingma (1973) published a study on the treatment of pseudoarthrosis of shaft fractures.

The study described in this thesis was based on the case histories of patients admitted to the Groningen University Hospital for primary treatment of a femoral shaft fracture during the period 1958 through 1969. Patients younger than 17 and those with fractures due to tumour growth were excluded.

The surviving patients were summoned to the out-patient clinic for a follow-up. More than 250 data were recorded per patient and analysed with the aid of a computer.

A similar study was published in 1963 by Dencker, who during the period 1952 through 1954 investigated virtually all cases of femoral shaft fractures in adults in Sweden. Dencker concluded that conservative treatment is the method of choice in the routine management of femoral shaft fractures.

The period covered in Dencker's study precedes the period considered in this study by about ten years. During this decade Küntscher nailing with reaming of the medullary cavity and A.O.-compression plate osteosynthesis have been evolved.

These new techniques were used in many of the cases discussed in this study, and this provides the opportunity to establish whether the new operative techniques can indeed be regarded as assets. The outcome of this study may lead to a modification of Dencker's conclusion.

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Chapter II
Definition, anatomy and fracture mechanics

II.1. INTRODUCTION AND DEFINITION

The femur is one of the long bones of the body. Its ends or extremities are adapted to articular function and consist for the most part of cancellous bone. The part in between the ends consists of a tube of compact bone and is known as shaft.

For purposes of comparison it is of importance that publications on femoral shaft fractures define exactly which part of the femur is regarded as shaft. This has been done in some publications (Carr and Miller 1958; Dencker 1963).

In this study the femoral shaft is defined as that part of the femur that consists of compact bone. This ensures that all femoral shaft fractures discussed involve the same type of bone tissue so that the case material is homogeneous in this respect.

The shaft boundaries were chosen so as to be recognizable on anteroposterior radiographs of the femur. The lower edge of the lesser trochanter was accepted as the proximal boundary of the femoral shaft. As distal boundary is accepted a line which parallels the joint space of the knee at a distance equal to the width of the condyles. This line roughly coincides with the upper edge of the suprapatellar pouch and with the boundary between diaphysis and metaphysis. The boundaries are marked in fig. 2 which, for comparison, also indicates the demarcations used by Carr and Miller and by Dencker.

In this study the term femoral shaft fracture applies to all fractures of which the fracture lines are localized within the above defined femoral shaft boundaries.

II.2. ANATOMY

The standard textbooks on anatomy consulted were: G. Wolf-Heidegger (1957) and J. Lang and W. Wachsmuth (1972).

The femoral shaft shows a slight forward bending. The medullary cavity varies in diameter and shape. The narrowest part is called isthmus, and is usually found immediately cranial to the midpoint. In transverse section the medullary cavity is circular at this level, whereas it has a more oval shape proximal and distal to the isthmus. The external circumference of the femoral shaft is more triangular than circular. The shaft has an anterior, a medial and a lateral surface. The junction of the lateral and the medial surface is marked by a ridge: the linea aspera.

The muscles of the thigh are enveloped in a sheet of firm fibrous tissue: the fascia lata. On the lateral aspect this is reinforced to form the iliotibial tract. Three septa of connective tissue extend from the linea aspera to the fascia lata. These septa divide the muscles of the thigh into three groups: extensors, flexors and adductors. These respective groups consist of the following muscles:

extensors: vastus lateralis, vastus intermedius, vastus medialis, rectus femoris (quadriceps femoris); sartorius;
innervated by the femoral nerve.

flexors: semitendinosus, semimembranosus, biceps femoris;
innervated by the sciatic nerve.

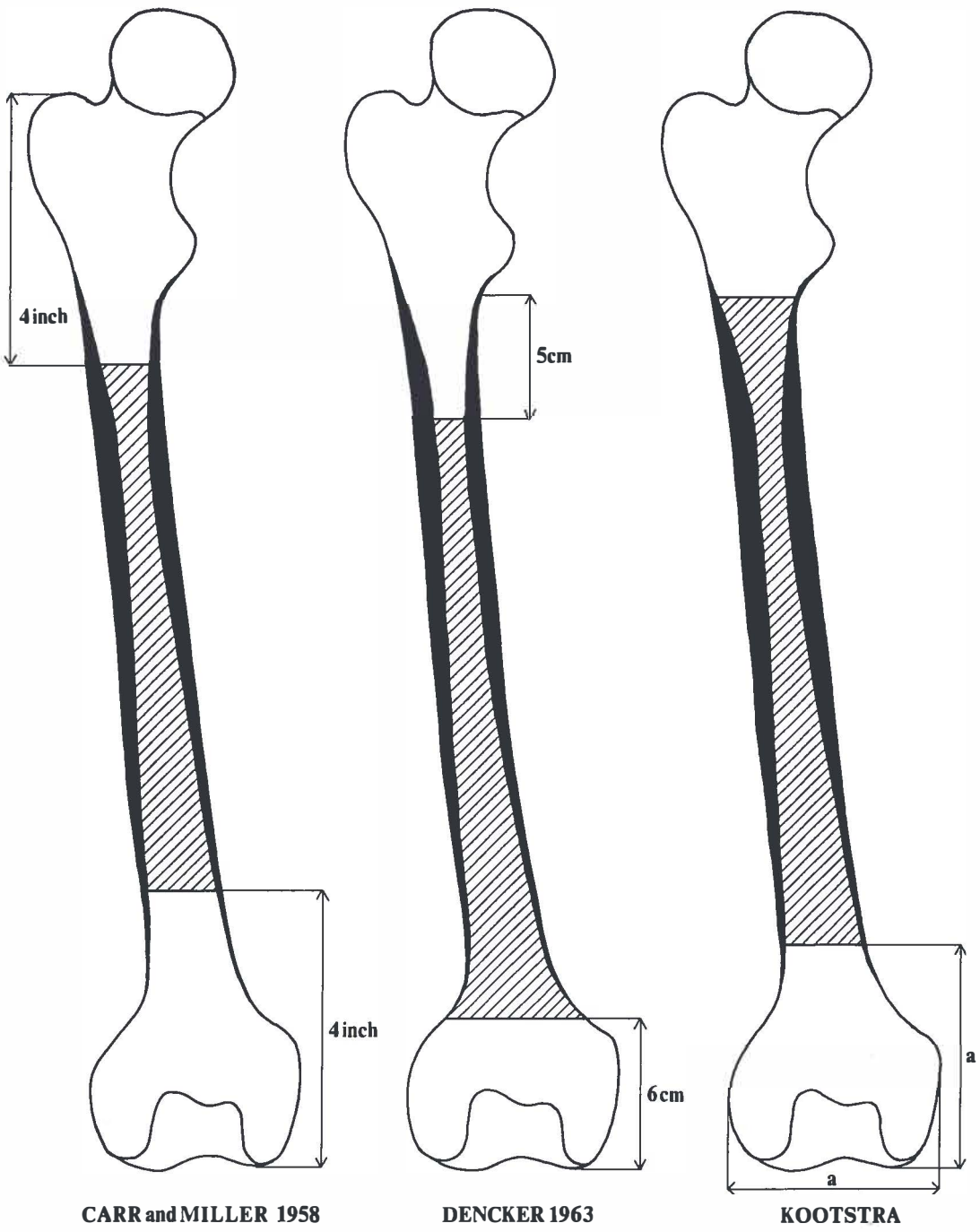

Figure 2. Definition of the femoral shaft as indicated in the literature and in the present study. The hatched area demarcates the part defined as shaft. The method of determining the distal boundary is indicated.

adductors: adductor brevis
adductor longus
adductor magnus
pectineus
gracilis
innervated by the obturator nerve.

The pectineus is innervated also by the femoral nerve, and the adductor magnus by the sciatic nerve.

Muscles attached to the posterior side of the femoral shaft are: pectineus, adductor brevis, adductor magnus, adductor longus and gluteus maximus. Muscles which have their origin on the femoral shaft are the vastus lateralis, vastus medialis and the short head of the biceps femoris; on the anterior side, the vastus intermedius and the articularis genus have their origin.

The principal blood vessel of the thigh is the deep femoral artery. One of its first branches is the lateral circumflex femoral artery which supplies blood to, among others, the extensors. Other branches supply blood to the adductors. At a more distal level the deep femoral artery produces two major branches: the first and the second perforating artery; and it ends in the third perforating artery. These arteries pass through the insertion of the adductor magnus, and supply the flexors with blood.

The superficial femoral artery produces only one branch extending to the thigh muscles: the muscular branch of the femoral artery which supplies blood to the vastus medialis.

The femoral shaft itself has an endosteal and a periosteal blood supply. The endosteal blood supply is ensured by the nutrient artery, which as a rule is a branch of the first perforating artery. This artery enters the shaft through the nutrient foramen. The latter is localized near the middle of the shaft close to the linea aspera, and gives access to a tunnel extending over a distance of a few centimetres in cranial direction. In some cases there is a second nutrient foramen with a second nutrient artery at a more distal level (Laing 1953).

The periosteal blood supply is ensured by numerous small vessels from the adjacent soft tissues.

The role of the circulation in fracture healing has been studied in particular by Trueta and Cavadias (1955, 1965).

There are a number of conventional and less conventional surgical approaches to the femoral shaft. Conventional approaches are the direct and the indirect lateral approach. In the direct approach one divides the iliotibial tract in the direction of the fibres and proceeds straight to the femoral shaft through the vastus lateralis and vastus intermedius. In the indirect or so-called posterolateral approach one divides the iliotibial tract and proceeds to the shaft by a route passing behind the vastus lateralis and in front of the intermuscular septum. Branches of the perforating arteries are encountered in this approach.

Less conventional approaches are the anterior and the medial. In the anterior approach an incision is made in the line which extends from the superior anterior iliac spine to the lateral aspect of the patella. After dividing the intermedius muscle, one proceeds to the femoral shaft between the rectus femoris and the vastus lateralis (Henry 1966).

The use of this incision could lead to connective tissue formation between the extensors and the shaft, resulting in limitation of knee function.

The medial approach is occasionally used when correction of a femoral shaft fracture entails work on the superficial femoral artery. In that case the approach to the shaft is made between the sartorius on the one hand and the adductor magnus and vastus medialis on the other; in this approach the superficial femoral artery is encountered.

There is still another approach to the shaft, the posterior approach, which is virtually always avoided in view of the risk of a lesion of the sciatic nerve.

Dislocation in femoral shaft fractures is a resultant of three forces: impinging violence, muscle action and gravity. The impinging violence is self-evident. Muscle action and force of gravity are responsible for some typical dislocations.

a. Upon fracture of the proximal shaft segment, the proximal fragment is abducted by the gluteus medius and gluteus minimus, while the iliopsoas muscle causes flexion and exorotation of the fragment. The distal fragment is pulled in median direction by the adductor magnus.
b. Upon fracture of the mid-segment of the shaft, the proximal fragment is pulled in median direction by the adductors, while the weight of the foot causes exorotation of the distal fragment.

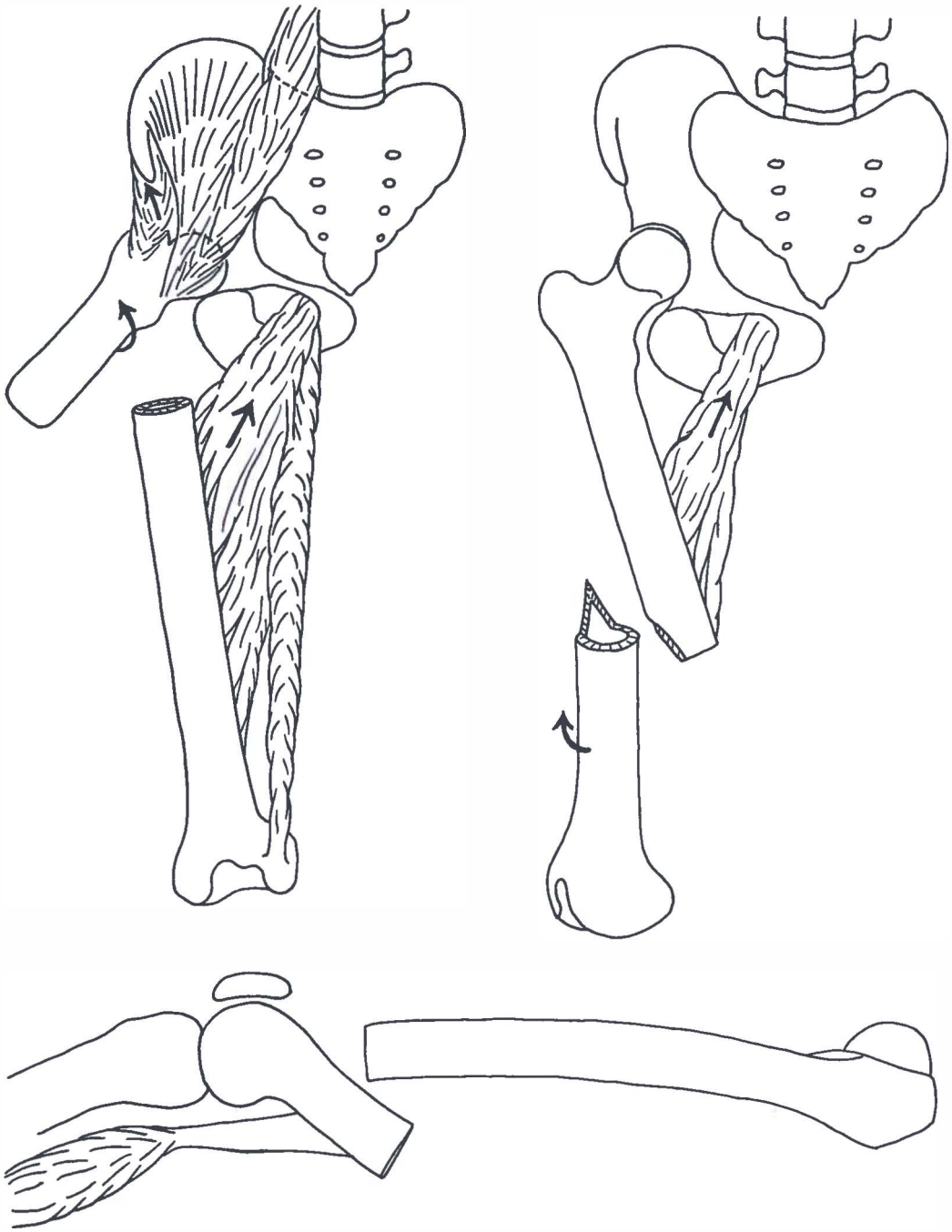

Figure 3. Three typical dislocations as, dependent on the fracture site, they can occur in the case of fracture of the femoral shaft.

c. Upon fracture of the distal shaft segment, and even more in the case of a supracondylar fracture, the action of the gastrocnemius muscle causes flexion of the distal fragment.

These typical dislocations are illustrated in fig. 3. Femoral shaft fractures as a rule entail longitudinal dislocation as well. This is caused by the muscles which span the femoral shaft. On the flexor side these are the flexors, with the exception of the short head of the biceps femoris. On the extensor side the rectus femoris, sartorius and gracilis span the shaft. The iliotibial tract, on which the tensor fasciae latea inserts, also contributes to longitudinal dislocation.

II.3. FRACTURE MECHANICS

Perkins (1956) pointed out the importance of understanding the direction in which and the force by which a fracture is caused. Such knowledge can provide information on lesions of the soft tissues, and can be useful in fracture reduction.

This study does not consider fractures due to tumour growth, but confines itself to femoral shaft fractures resulting from trauma.

The question arises as to whether a given accident mechanism results in a given fracture type. The many factors which play a role in fracture aetiology make it difficult to answer this question, and an exact analysis therefore seems impossible. Nevertheless there are ways of tracing a possible relationship between accident mechanism and fracture type. Studies have been made in which the effect of force applied to the femur has been calculated on the basis of a mechanical model (Pauwels 1948). Laboratory studies have been made in an effort to establish how human and animal cadaver femurs behave in response to various forces (Küntscher 1935; Evans et al. 1951; Hirsch et al. 1955; Hubbard 1973). The cortical bone density of the femoral shaft was studied by Atkinson and Weatherell (1967).

Finally, the results of the abovementioned studies were compared with clinical findings (Evans et al. 1951; Lissner et al. 1956; Alms 1961). Leitz (1970) demonstrated on the basis of the strength theory and experiments with cadaver fibulae that the course of the fracture plane is determined largely by shearing stresses.

The effect of a force sustained in an accident depends on the following factors:

a. magnitude of the force
b. direction of the force
c. nature of the force
d. nature of the bone
e. counteraction of soft tissues.

re a. The magnitude of the force is determined by the amount of energy applied to the femoral shaft in the accident.

re b. The direction of the force applied to the femoral shaft can be:
- tension
- compression
- shear
- torque.

The simplest example of a force is axial tension or compression, in which the force acts in the direction of the axis of the femur. The stresses involved here are opposed to each other.

Rauber (1876) demonstrated that bone tissue offers less resistance to tensile than to compressive stress. This is also evident when a force is applied perpendicular to the axis direction, producing bending. The effect of this procedure was studied by Küntscher (1935) and by Evans et al. (1951) on human cadaver femurs sprayed with varnish. The first cracks in the varnish occurred on the convex side at the site of maximal tensile stress. When the force was increased, interruption of continuity first occurred on the convex side, perpendicular to the direction of the femoral axis. On the concave side compressive stresses occurred, which produced shearing stresses in the bone tissue so that the fracture line assumed an oblique course on this side.

Extrapolating these experimental findings to clinical practice, the following can be stated. When the oblique segment of the fracture line is very short, a transverse fracture exists. With a somewhat longer oblique segment of the fracture line we have an oblique fracture type; and simultaneous interruption of continuity in two directions results in a more or less triangular fragment, which is sometimes called butterfly. Its German designation is 'Biegungskeil' (bending-wedge), and this term reflects the causative mechanism.

Torque applied to cadaver femurs resulted in

fractures with a spiral plane (Hubbard 1973), the course of which is again determined by the shearing stresses involved (Leitz 1970).

The experimental arrangements simplify and schematize reality. In actual practice we are likely to encounter combinations of tension, compression, shear and torque, resulting in a very complex stress pattern (Swaan 1970).

re c. The nature of the force can be static or dynamic. Evans et al. observed in laboratory tests that static and dynamic forces produced identical deformation patterns. Hirsch et al. studied the effects of static and dynamic force and those of the combined forces on rabbit cadaver femurs. Extensive comminution of the shaft occurred when a blow with a heavy object (dynamic force) was combined with torque (static force).

re d. The nature of the bone is determined by the physical properties of the bone tissue. Adult long bones differ from those of children in that they are less elastic; and the elasticity further diminishes with increasing age. Moreover, breaking strength and elasticity are not the same throughout the bone. Atkinson and Weatherell studied the distribution of the cortical bone density over various levels of the femoral shaft. The density was found to vary with the level and with age. Its distribution over the shaft shows a spiral pattern, which is even more pronounced with increasing age and osteoporosis. Since a correlation can be assumed between bone density and bone strength, variations in density should be reflected in the femoral shaft fractures observed in clinical practice.

re e. The counteraction of the soft tissues is the least readily assessable factor in fracture aetiology. Pauwels demonstrated on the bases of a model that the iliotibial tract plays an important role in absorbing a bending force in the frontal plane. Another example of the importance of the soft tissues is the ability of the ligaments of the hip-joint to absorb torque applied to the femur. These ligaments can be wound up like a watch spring.

In view of the various factors which play a role in the aetiology of femoral shaft fractures, a number of hypotheses on the relationship between accident mechanism and fracture type can be formulated. When the mobility of the hip-joint is diminished after a femoral neck fracture or as a result of osteoarthritis, torque can no longer be absorbed in the hipjoint. Consequently (and also because of the changes in cortical bone density), it is probable that spiral fractures will occur more frequently in more advanced age. Hubbard (1973) found in cadaver femurs that 'the breaking torque moment was inversely proportional to age'. It is also probable that these fractures are more common in aged women than in aged men, for as a rule the osteoporosis which accentuates the spiral pattern in cortical bone density, is more marked in women than in men.

Studies on varnished femurs exposed to an excentric force have shown that maximal tensile stresses occurred on the proximal side of the neck and on the anterolateral aspect of the shaft. Atkinson and Weatherell found that cortical bone density diminished with age, particularly on the anterolateral aspect of the femoral shaft. The strength of the iliotibial tract also diminishes with age, so there are several factors which – in conjunction – indicate the likelihood of bending fractures with increasing age.

Finally, the question arises as to how one should explain a so-called comminuted fracture. This type of fracture involves a large part of the shaft with numerous fragments of indeterminate shape. These fractures probably result from a combination of a large amount of energy and direct impingement of an abrupt force on the shaft (Hirsch et al. 1955). The stresses which occur in the bone are so great that the limit of elastic deformation is exceeded several times.

In clinical work, comminuted fractures can be expected in accident situations involving a large amount of energy and an abrupt force. Femoral shaft fractures in war casualties, too, are often comminuted. Data from these kind of patients are not available, so these fractures will be left undiscussed in this study.

II.4. SUMMARY

The femoral shaft is defined in this chapter. The definition holds that the shaft is that part of the femur that consists of compact bone. The boundaries of the shaft on anteroposterior radiographs are demarcated.

The anatomy of the thigh is then discussed, and

surgical approaches are briefly outlined. The groups of muscles involved in a number of typical dislocations are indicated.

The relationship between accident mechanism and fracture type is considered. On the basis of theoretical considerations and laboratory experiments with cadaver femurs, the hypothesis is advanced that bending forces will result chiefly in transverse and oblique fractures, in some instances with the formation of a triangular fragment.

On the same grounds it is plausible that spiral fractures occur as a result of torque, to which the femur is less resistant with increasing age.

In comminuted fractures the magnitude of the force applied is probably such that the limit of elastic deformation is exceeded several times, while at the same time the force impinges directly on the shaft.

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Chapter III
Material and methods

III.1. PATIENTS

This study is based on all adult patients admitted to the Groningen University Hospital for primary treatment of a femoral shaft fracture during the period from 1st January 1958 through 31st December 1969 (12 years). The age of 17 was accepted as the lower limit of adulthood. An individual's skeleton is in fact fully grown (adult) at the moment of closure of the epiphyseal plates. This is the case in the majority of the 17-year-old, and for practical reasons this age limit was preferred to the moment of closure of the epiphyseal plates. Fractures resulting from primary or metastatic tumour growth, the so-called 'pathological' fractures, were excluded.

Patients who had first been treated elsewhere and were referred to the University Hospital because of disturbed healing, were not included in this study.

The data available thus concern a total of 329 patients with 335 femoral shaft fractures.

Each fracture was assigned a three-digit number in chronological order. The numeration ranges from 001 to 338 (numbers 088, 327 and 331 were not assigned). In order to prevent patients with bilateral femoral shaft fractures from being counted double and thus supplying non-independent observations to the material for statistical analysis, one of the fractures in each of these cases (numbers 022, 176, 193, 255, 290 and 308) was eliminated by lot. Thus there remained 329 patients with 329 femoral shaft fractures.

The designations 'patients with femoral shaft fracture' and 'femoral shaft fractures' will henceforth be used indiscriminately in this study.

Case histories and radiographs were collected and studied.

Surviving patients were summoned to the outpatient clinic for a follow-up during the years 1969, 1970 and 1971. The interval between time of accident and follow-up was always at least two years.

The data collected were transferred to punch cards, four of which were used per patient. The data were analysed with the aid of the Computer Centre, State University, Groningen.

III.2. METHODS OF STATISTICAL ANALYSIS

In statistical analysis, use was made of the Chi-square test and the Mann-Whitney U-test (Siegel 1956). The level of significance was set at 5% – $p < 0.05$.

III.3. REFERENCES

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Chapter IV
The phenomenology of the femoral shaft fracture

IV.1. INTRODUCTION

This chapter describes and discusses the phenomenology of the femoral shaft fracture. The femoral shaft fracture is charted, so to speak. The findings are compared with those presented in five other suitable publications on femoral shaft fractures. Some aspects of the material on which these publications are based, are listed in table 1.

Publications on case material subject to selection, e.g. on the basis of method of treatment, have not been included because they form no representative random sample.

The femoral shaft fracture incidence per age group per average one-thousand of population was calculated for Sweden by Dencker. A similar calculation can be made for the series of patients discussed in this study, with certain reservations which will be explained in the following paragraphs.

During the period 1958 through 1969, accident victims in the Province of Groningen were taken to one of the four hospitals in this Province. One of these hospitals was situated in Winschoten, while the remaining three were in the city of Groningen. The Winschoten hospital took care of the area surrounding the town of Winschoten.

Table 1. Survey of comparable literature

Year of publication	Author, hospital, city and country	Period studied	Definition of femoral shaft	Lower age limit	Number of cases studied	Statistical analysis	Pathological fractures eliminated
1958	Buck-Gramcko, H., Darmstadt Municipal Hosp., West Germany	1954 through 1956	no	15	103	no	yes
1961	Martyn J. W. and P. F. McGoey, St. Michael's Hospital, Toronto, Canada.	1950 through 1960	no	?	100	no	no
1963	Dencker, H. M., all Swedish Hospitals except four	1952 through 1954	yes	17	1003	yes	yes
1970	Blichert-Toft, M. and A. Hammer, Glostrup Hospital, Copenhagen, Denmark.	1959 through 1968	yes, like Dencker's	15	82	no	yes
1971	Suiter, R. D. and A. J. Bianco, Mayo Clinic, Rochester, USA.	1956 through 1965	no	15	131	no	yes

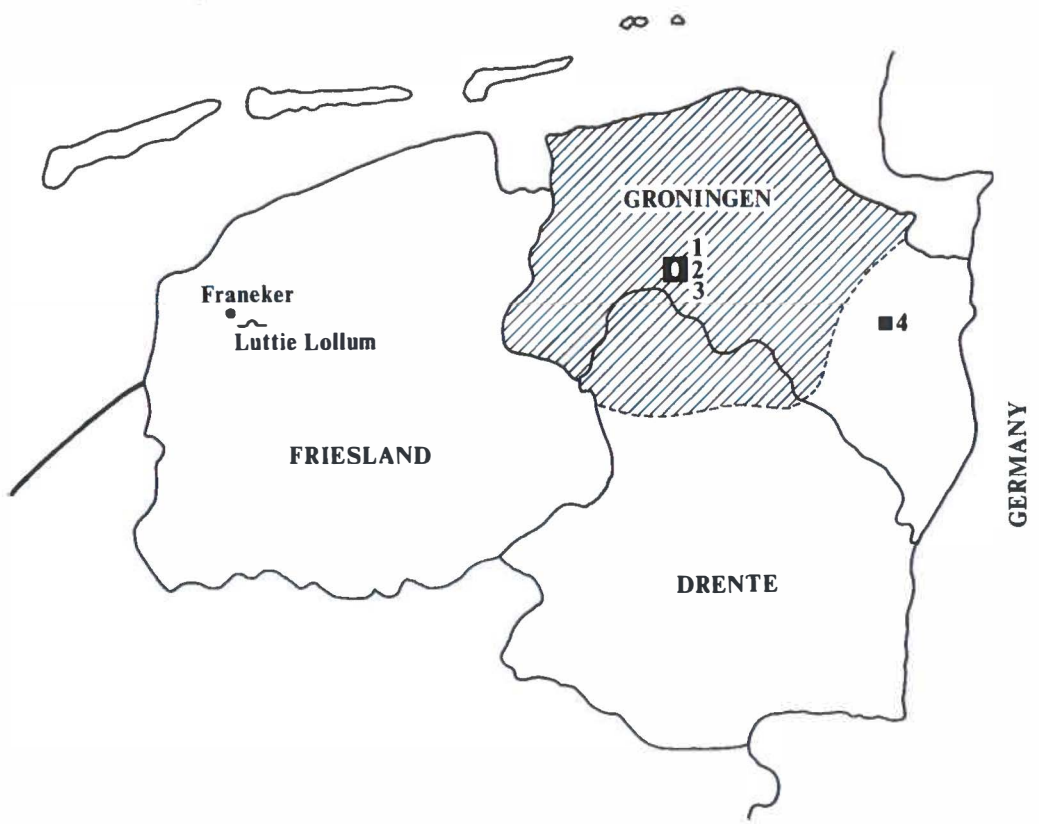


Figure 4. Area covered by the hospitals of the city of Groningen with regard to accident victims, in the period from 1958 through 1969. Luttie Lollum near Franeker is the place where the femora of figure 1 are found.

The three city hospitals covered the remainder of the Province of Groningen as well as a part of the Province of Drente (the so-called 'head of Drente'). The population of the latter area roughly corresponds with that in the Winschoten area. It can therefore be assumed, with some reservation, that during the period of observation the three hospitals in the city of Groningen covered an area which, in population, equalled the Province of Groningen. The situation is outlined in fig. 4, in which the shaded area is the area covered by the three city hospitals.

An impression of the distribution of accident victims over the three hospitals in the city of Groningen can be gained from an Interim Report (1965) and from the figures presented by the Municipal Medical Service over a decade within the 12-year period of observation (table 2).

Table 2. Survey of destinations of accident victims transported by the Groningen Municipal Medical Service.

year	University Hospital	Catholic Hospital	Protestant Hospital
1960	666	25	10
1961	688	50	12
1962	683	39	1
1963	628	35	1
1964	703	42	1
1965	798	20	3
1966	777	38	8
1967	872	70	23
1968	1070	70	73
1969	1151	77	74

These figures pertain to the accident patients in the city of Groningen. It can be maintained that the majority of these accident victims were taken to the University Hospital. It is assumed that the figures for the city of Groningen reflect a distribution which applies to the entire area covered by these hospitals.

In view of these data and with the abovementioned reservations, the population of the Province of Groningen can be regarded as the population in which the femoral shaft fractures of this series occurred. The composition of the population of the Province of Groningen during the period of observation is known (Central Bureau of Statistics). It is with these findings that the calculation introduced in the next section was made.

IV.2. FREQUENCY

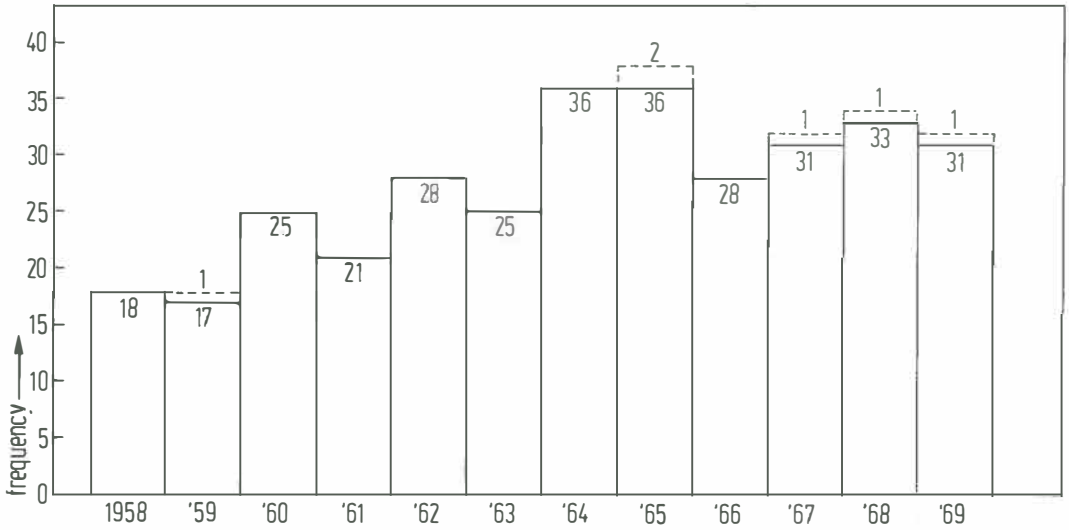


Figure 5. Distribution over the period 1958 through 1969. Dotted lines indicate bilateral femoral shaft fractures.

The graph in fig. 5 shows the distribution of patients over the years 1958 through 1969.

The sex distribution is shown in fig. 6, indicating that 22.2% of patients were female and 77.8% were male (Dencker: 27% female and 73% male; Martijn and McGoey: 41% female and 59% male; Blichert-Toft and Hammer: 21.5% female and 78.5% male).

Figure 6. Sex distribution.

The age distribution in decades is shown in fig. 7. The first age group includes patients aged 17, 18 and 19 (age limit: 17).

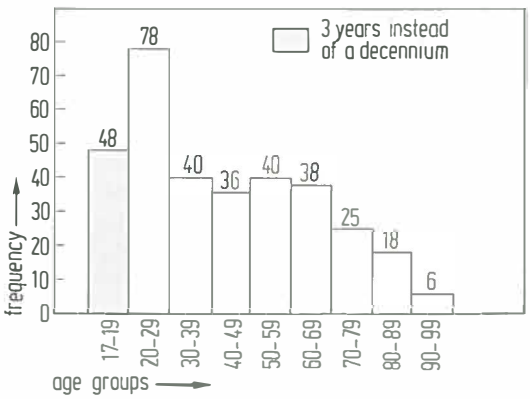


Figure 7. Age group distribution.

Table 3 lists the average population of the Province of Groningen per age group and per sex.

Table 3. Average population of the Province of Groningen during the 12-years period studied.

age groups	males	females
17–19 years	13054	12245
20–29 „	36085	33719
30–39 „	29855	29465
40–49 „	28939	29787
50–59 „	26593	27898
60–69 „	20669	22536
70–79 „	12193	14001
80–89 „	4063	4977
90–99 „	364	530

The femoral shaft fracture incidence per 1000 population was calculated and is presented in table 4. Figures of age group 90–99 were too small to allow a reliable calculation.

Table 4. Number of patients with a femoral shaft fracture per 1000 average population of the Province of Groningen during the period studied.

age groups	males	females
17–19 years	3.06	0.65
20–29 „	1.91	0.26
30–39 „	1.50	0.16
40–49 „	1.17	0.06
50–59 „	1.20	0.28
60–69 „	1.35	0.44
70–79 „	0.65	1.21
80–89 „	1.47	2.41
90–99 „	(10.98)	(3.77)

The incidence per sex, per decade, per 1000 average population, is shown in fig. 8, along with the graph plotted by Dencker.
Dencker's graph and that pertaining to the series under discussion are of virtually the same shape; but since the present series covers a period of 12 years and that of Dencker a period of 3 years, they differ by a factor 4.

Fig. 8 invites the following comment:

* In males, femoral shaft fractures occur most frequently at an early age. The incidence gradually diminishes with increasing age, and attains its lowest value in age group 70–79, after which another increase occurs.
* The frequency in females differs from that in males, the incidence being lowest in age group 40–49. After this there is an increase so marked that females of age group 80–89 are more likely to sustain a femoral shaft fracture than males of age group 20–29. This marked increase in femoral shaft fracture incidence in females after age 50 can only be explained on the basis of a constitutional factor, i.e. the hormonal change during and after the climacteric, which is associated with osteoporosis and increases the fragility of the femoral shaft.

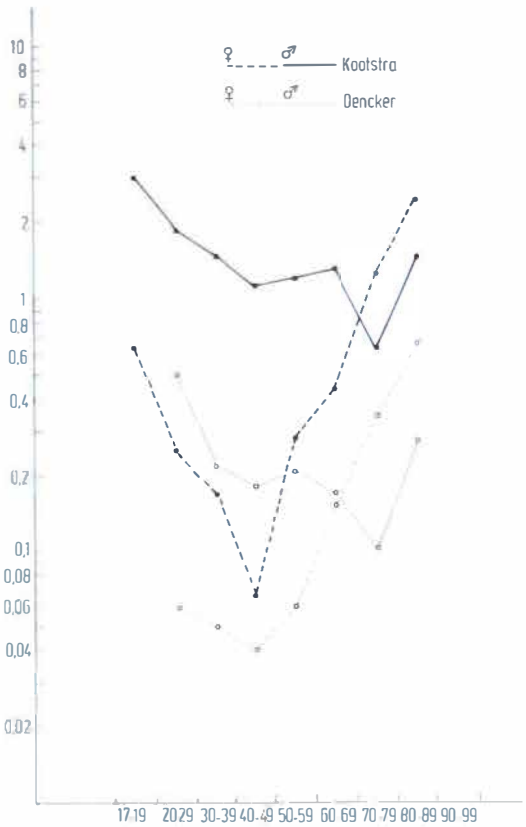


Figure 8. Logarithmic linear graph showing the femoral shaft fracture incidence per age group per sex per 1000 average population for Dencker's and the present series.

The distribution over the age groups was studied, but the number of patients in group 80–89 and group 90–99 was too small for effective statistical analysis. The patients of these two age groups were added to those of group 70–79 to

form age group '70 and over', which now includes 49 patients – a number more suitable for statistical analysis. The percentage of patients aged 70 and over is 14.9%. Dencker obtained the same percentage. In the series of Blichert-Toft and Hammer, the corresponding figure is 15%. Martyn and McGoey reported 23%, but this information is unreliable because their series included pathological fractures.

Table 5 indicates the distribution of femoral shaft fractures over the age groups per sex. The distribution in females differs significantly from that in males. $\chi_{(6)}^2 = 62.28$ ($p < 0.001$).

Table 5. Distribution over the age groups per sex.

age groups	males	females
17–19 years	40 (83%)	8 (17%)
20–29 „	69 (88%)	9 (12%)
30–39 „	35 (88%)	5 (12%)
40–49 „	34 (94%)	2 (6%)
50–59 „	32 (80%)	8 (20%)
60–69 „	28 (74%)	10 (26%)
70 and over	18 (37%)	31 (63%)

Fig. 9 shows the distribution over the decades in males and females in a graph, leaving age group 17–19 undiscussed.

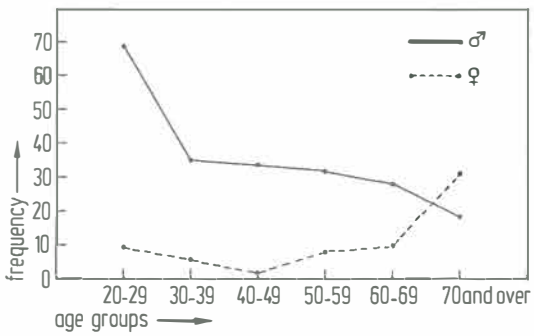


Figure 9. Age group distribution per sex.

The large percentage of female patients in age group 70 and over (63% in this series) was also found by Dencker and by Blichert-Toft and Hammer, whose respective percentages are 72% and 66%.

Table 6 indicates the frequency as distributed over the months of the year.

Table 6. Frequency per month

month	number
January	9
February	16
March	23
April	21
May	29
June	29
July	35
August	30
September	39
October	30
November	37
December	31
total	329

A striking feature is the small number of femoral shaft fractures in the months of January; could this have anything to do with the good resolutions for the new year?

The months were grouped in four clusters, corresponding with the four seasons. Table 7 gives the distribution over the seasons.

Table 7. Frequency per season

season	number	%
winter (December through February)	56	17
spring (March through May)	73	22
summer (June through August)	94	29
autumn (September through November)	106	32
total	329	100

IV.3. PRE-EXISTENT DISEASES

At the time of the accident, 94 patients (28.6%) had one or several pre-existent diseases. The latter are divided into general diseases and those involving the fractured leg: the socalled 'local homolateral diseases.'

Table 8 indicates the frequency of pre-existent diseases.

Table 9 indicates the distribution of patients with pre-existent disease over the age groups. This distribution is not even but shows a significant

difference between the younger and the older age groups. $\chi_{(6)}^2 = 49.53$ ($p < 0.01$).

Table 8. Frequency of pre-existent diseases.

pre-existent diseases	number	%
GENERAL		
respiratory system	18	5.5
circulatory system	24	7.3
digestive tract	12	3.6
urogenital system	5	1.5
cerebrospinal system	16	4.9
endocrine diseases	9	2.7
psychiatric disorders	15	4.6
other systemic diseases	10	3.0
pre-existent abnormalities of suspensory and locomotor apparatus	22	6.7
LOCAL (homolateral)		
hip-joint disease (osteoarthritis)	13	4.0
condition after hip fracture	6	1.8

Table 9. Distribution of pre-existent diseases over the age groups.

age groups	no pre-existent diseases	pre-existent diseases
17–19 years	45 (94%)	3 (6%)
20–29 „	65 (83%)	13 (17%)
30–39 „	38 (75%)	10 (25%)
40–49 „	29 (81%)	7 (19%)
50–59 „	23 (57%)	17 (43%)
60–69 „	24 (63%)	14 (37%)
70 and over	19 (39%)	30 (61%)

IV.4. TYPE OF ACCIDENT

The type of accident sustained was established for all patients. Eight different accident types were distinguished. Fractures caused by bullets did not occur during the period of observation. In four cases the accident type could not be established on the basis of the data available. Five patients had accidents not classifiable under any of the eight headings used. The accident types and the distribution of fractures over these types are given in fig. 10.

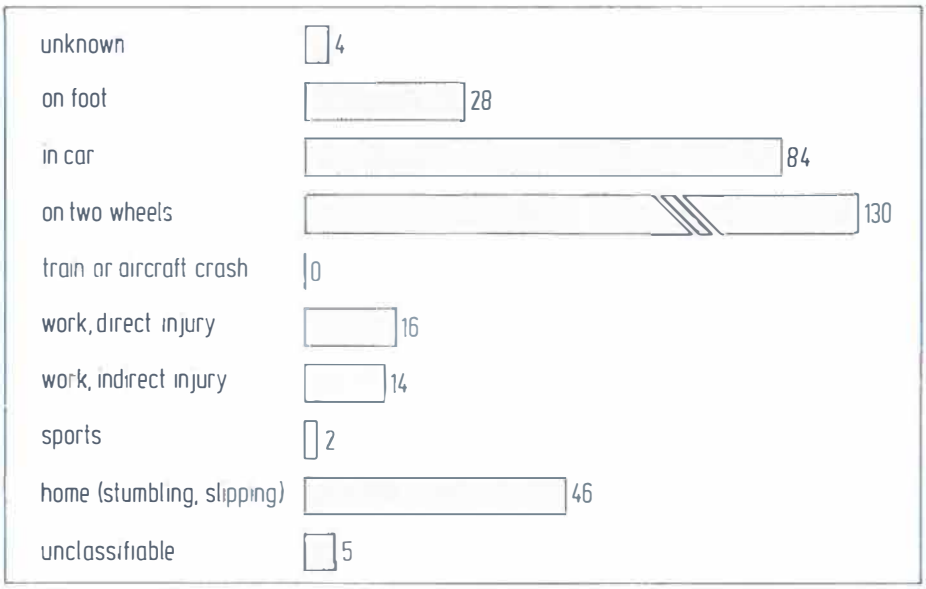


Figure 10. Distribution over accident types.

The heading 'work, direct injury' refers to the thigh being crushed by a heavy weight (e.g. a collapsing wall) in the work situation. Incarceration of the thigh is also classified as direct injury. The heading 'work, indirect injury' covers the patients who sustained a fall in the work situation. This group also includes patients whose foot or lower leg was incarcerated and whose body was subjected, to, say, a rotatory force.

For the purpose of statistical analysis, four groups were distinguished:

1. unknown and unclassifiable
2. traffic
3. work
4. home (e.g. stumbling, slipping).

The two patients with a femoral shaft fracture sustained in sports have been included in the group work (assuming that their injury resembled the injuries in this group as to amount of impinging violence). Dencker listed 34 patients who sustained a femoral shaft fracture while practising sport (3.3%). He formulated no criteria for a sports injury and did not specify the branches of sport involved (in Sweden, there may have been many ski-ing injuries).

In the present series all fractures sustained in field and track sports or indoor sports were included in the sports group. Femoral shaft fractures sustained in motor-cross or speedway races were included in the group 'on two wheels'.

Table 10. Frequency per accident group.

accident groups	number	%
unknown and unclassifiable	9	3
traffic	242	74
work	32	10
home	46	14
total	329	

Table 10 shows the frequency per accident group. Almost three-quarters of the fractures were sustained in traffic accidents. Dencker's percentage is considerably smaller (57%). The difference could probably be due to the lower traffic density in Sweden during the period 1952 through 1954 than in the Province of Groningen some ten years later. The percentual difference in traffic accident victims is not likely to be due to the difference in definition of the femoral shaft. Blichert-Toft and Hammer reported 73%, which is in closer agreement with the percentage in the present series. The percentages for the work and home groups cannot be compared because the other series comprise no pertinent data.

The distribution of the accident types over the age groups is shown in table 11.

Table 11. Accident and age

age groups	traffic	work	home
17–19 years	45 (94%)	3 (6%)	–
20–29 „	69 (91%)	7 (9%)	–
30–39 „	32 (82%)	6 (15%)	1 (3%)
40–49 „	31 (86%)	5 (14%)	–
50–59 „	31 (81%)	3 (8%)	4 (11%)
60–69 „	21 (56%)	5 (14%)	11 (30%)
70 and over	13 (28%)	3 (7%)	30 (65%)

The home group is found to be largest in age group 60–69 and group 70 and over. In the latter group, 65% of the patients sustained the femoral shaft fracture in an accident at home.

The distribution of the accident types over the sexes is presented in table 12.

Table 12. Accident and sex.

sex	traffic	work	home
male	205 (82%)	32 (13%)	13 (5%)
female	37 (53%)	–	33 (47%)

The patients who sustained a femoral shaft fracture in the work situation include no women. The home group shows a female predominance, in contrast to the traffic group. This difference is statistically significant. $\chi_{(2)}^2 = 82.02$ ($p < 0.001$).

The left-right distribution was also established: 179 fractures were on the left and 150 on the right. This difference is not significant. $\chi_{(1)}^2 = 2.55$. Dencker found a non-significant predilection for the right side. Dencker's data along with those on the present series are shown in table 13.

Table 13. Left-right distribution in Dencker's and in the present series.

	left	right
Dencker	471 (46,9%)	532 (53,1%)
Kootstra	179 (54,4%)	150 (45,6%)

The difference between the two series is statistically significant. $\chi_{(1)}^2 = 5.20$ ($p < 0.05$). The possible cause of this difference will be discussed later.

Table 14 indicates the left-right distribution in relation to the type of accident.

Table 14. Accident group and laterality.

accident group	left	right
traffic	142 (59%)	100 (41%)
work	8 (25%)	24 (75%)
home	22 (48%)	24 (52%)

The table shows that the left femur is often involved in traffic accidents, and the right often in work accidents. Traffic accidents and work accidents differ significantly in left-right distribution. $\chi_{(6)}^2 = 11.61$ ($p < 0.001$). The left-right distribution in home accidents is almost equal. It seems interesting to study the possible cause of this difference between traffic and work injuries. Table 15 lists the types of accident and the corresponding left-right distribution.

Table 15. Accident type and laterality.

accident type	left	right
traffic, on foot	16 (55%)	12 (45%)
traffic, in car	49 (58%)	35 (42%)
traffic, on two wheels	77 (59%)	53 (41%)
work, direct injury	5 (31%)	11 (69%)
work, indirect injury	3 (21%)	11 (79%)
sports	–	2 (100%)
home	22 (48%)	24 (52%)

The three traffic categories all show a predilection for the left, while the two work categories show a predilection for the right. A study of the work accidents gives no insight into the cause of the predilection for the right femur. The predilection for the left femur in the traffic accidents might be due to the fact that traffic keeps to the right in The Netherlands. If so, then a predilection for the right should be observed in traffic accidents in countries where traffic keeps to the left. Dencker's study concerns Sweden, where traffic did keep to the left at that time; but Dencker presents no left-right distribution in relation to traffic. On the whole his series includes more right-sided than left-sided fractures, but the difference is small.

Dencker's series includes a smaller percentage of traffic accident victims than the present series (57% versus 74%), and consequently an effect of traffic, if any, is less readily distinguishable.

Since traffic in Sweden was keeping to the left at the time of Dencker's study, the significant difference in left-right distribution between the two series could perhaps be ascribed to the fact that traffic kept to different sides of the road in the two series.

The relationship between accident type and open or closed femoral shaft fracture was also considered. In three cases (0.9%) it could not be deduced from the available data whether the fracture had been open or closed.

A fracture is regarded as an open fracture if the continuity of the skin at the fracture site is interrupted, from the inside or from the outside. By this definition, 14.6% of the femoral shaft fractures in the present series are open fractures. Dencker found a percentage of 12%; Blichert-Toft and Hammer reported 26%, the Mayo Clinic 12.7%.

The open fractures in the present series were divided according to the severity of the skin lesion. Frequency and severity are given in fig. 11.

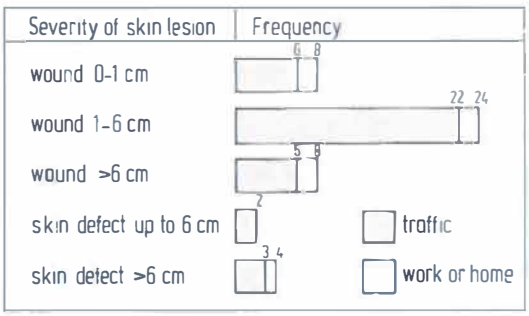


Figure 11. Frequency and severity of skin lesions.

The distribution of open fractures over the groups traffic, work and home is shown in table 16.

Table 16. Accident groups and open fractures.

accident groups	closed	open
traffic	200 (84%)	39 (16%)
work	26 (81%)	6 (19%)
home	45 (98%)	1 (2%)

The percentages of open fractures in the traffic group and the work group are not very different, 16% and 19%, respectively. Open fractures are rare in the home group.

In the traffic group, there are no important differences in the number of open fractures between the categories 'on foot', 'in car' and 'on two wheels'. This can be deduced from table 17.

Table 17. Traffic accidents and open fractures.

traffic accidents	closed	open
on foot	25 (89%)	3 (11%)
in car	69 (82%)	15 (18%)
on two wheels	106 (83%)	21 (17%)

Six open femoral shaft fractures occurred in the work situation: three from direct and three from indirect injury. In the direct injuries the skin lesion was more severe: the wound was larger than 6 cm in two, and in one there was a skin defect. The wounds in the indirect injuries were all smaller than 6 cm.

A survey of severe associated injuries is given in table 18. Patients with local circular injuries so severe as to necessitate primary amputation, are not included in this table.

Table 18. Frequency of severe associated injuries.

type of injury	number
muscle defect	4
lesion of extensor tendon	2
lesion of superficial femoral artery	3
lesion of popliteal artery	1
lesion of femoral vein	3
lesion of sciatic nerve	2

The case histories of the patients with these severe associated injuries will be discussed in Chapter XII.

The frequency of shock was also studied. The term shock is defined as indicating that, at admission to the accident service, the systolic blood pressure was less than 100 mm Hg and the pulse rate in excess of 120 beats per minute. These criteria are not optimal but they are the only practicable criteria in the context of this section. The data available were insufficient in 33 cases (10.3%). Of the remaining 296 patients 57 were in shock, at arrival at the accident service. The shock rate among the traffic accident victims was 24%, among the work accident victims 11 %, The relevant data are presented in Table 19.

Table 19. Accident groups and shock.

accident groups	no shock	shock
unknown and unclassifiable	6 (67%)	3 (33%)
traffic	163 (76%)	51 (24%)
work	25 (89%)	3 (11%)
home	45 (100%)	– (0%)
total	239 (80.4%)	57 (19.6%)

Table 20 categorizes the shock rate among the traffic accident victims.

Table 20. Traffic accidents and shock.

traffic accidents	no shock	shock
on foot	15 (65%)	8 (35%)
in car	53 (69%)	24 (31%)
on two wheels	95 (83%)	19 (17%)
total	163 (76%)	51 (24%)

Finally, the number of patients under the influence of alcohol upon arrival at the accident service was established, making use of the notes of the attending physician at the accident service. His recorded impression that the patient was under the influence of alcohol, although not an objective finding, was accepted and used. In two patients, no reliable data are available.

For 31 of the remaining 327 patients the attending physician mentioned in his notes that the patient was under the influence of alcohol; this is 9.5% of all patients. Of these 31 patients, 29 were traffic accident victims, one had sustained a fall at home and one was brought under the heading 'unclassifiable'. The percentage of patients with femoral shaft fractures listed as under the influence of alcohol is not representative of the number of accidents involving abuse of alcohol.

After all, a sober patient can be the victim of a drunken driver, and an inebriated patient can sustain an accident in a car driven by a sober person.

IV.5. ASSOCIATED INJURIES

The term associated injury is applied to:
1. a fracture, listed as such in the ICDA,
2. a dislocation, listed as such in the ICDA,
3. injuries to cranial, thoracic and abdominal organs,
4. large lacerated wounds.

Sprains and strains, contusions and minor cuts and chaps have not been listed as associated injuries.

The associated injuries are subdivided into:
a. general associated injuries;
b. local homolateral associated injuries.

The local homolateral associated injuries are associated injuries to the leg that sustained the femoral shaft fracture. General associated injuries are injuries to the remainder of the body.

A. GENERAL ASSOCIATED INJURIES

A general associated injury existed in 149 patients. The relationship between the presence of a general associated injury and accident groups is shown in table 21.

Table 21. Accident groups and general associated injuries.

accident groups	no general associated injuries	general associated injuries.
traffic	105 (43%)	137 (57%)
work	22 (69%)	10 (31%)
home	44 (96%)	2 (4%)

The different accident groups differ significantly in the distribution of the incidence of general associated injuries. $\chi_{(2)}^2 = 45.78$ ($p < 0.001$).

Of the 149 patients with a general associated injury, 92% come under the heading traffic, 7% under the heading work, and only 1% under the heading home. The distribution of general associated injuries over the various categories of traffic accident victims is shown in table 22.

A general associated injury was found in 77% of the patients who sustained a femoral shaft fracture while seated in a car; this is an impressively large percentage. The general associated injuries are charted in fig. 12.

Table 22. Traffic accidents and general associated injuries.

traffic accidents	no general associated injuries	general associated injuries
on foot	12 (43%)	16 (57%)
in car	19 (23%)	65 (77%)
on two wheels	74 (57%)	56 (43%)

Some notes on figure 12:

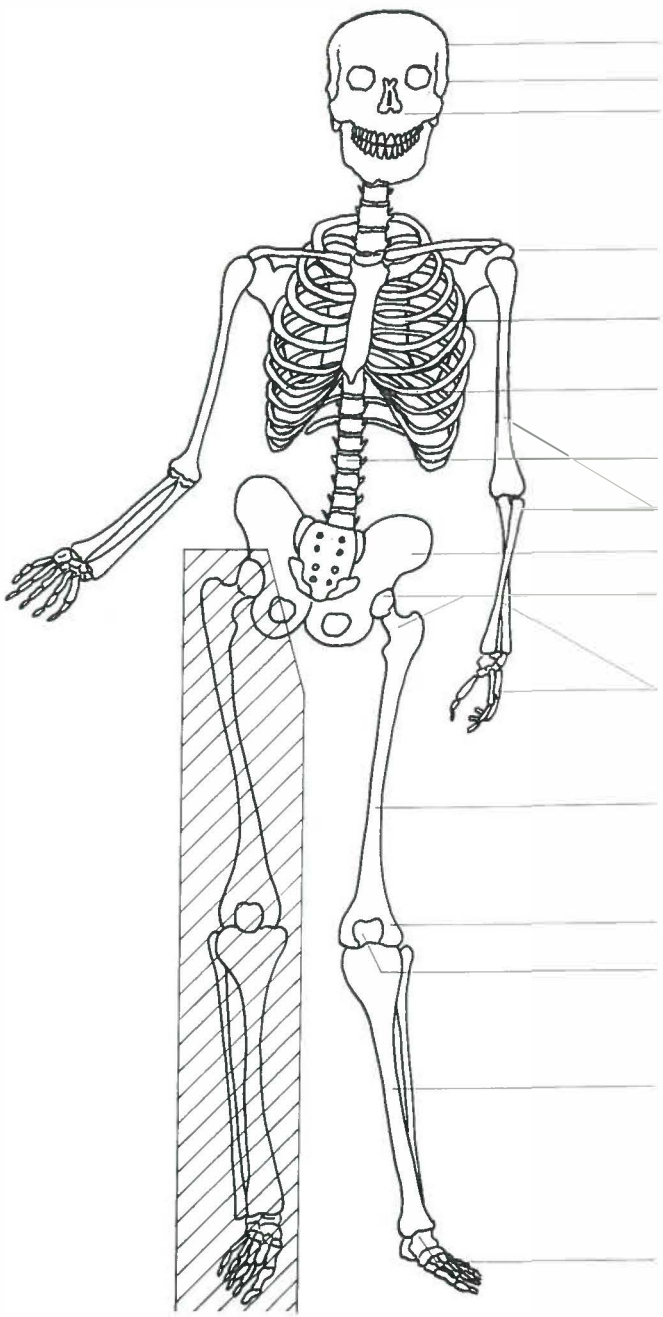
In all cases the diagnosis 'cerebral concussion' was made by a neurologist on the basis of the presence of one or several symptoms such as brief transient loss of consciousness, vomiting or retrograde amnesia.

The diagnosis 'severe craniocerebral injury' was reserved for patients with contusion of the brain, fracture of the base of the skull, or a combination of these.

The difference between thoracic injury with and without respiratory disturbances lies in the indication for controlled ventilation. Patients needing controlled ventilation were included in the group 'thoracic injury with severe respiratory disturbances'. The three patients with a vertebral fracture included one with paraplegia.

With regard to the list of 'other injuries' it is to be noted that four of the patients who died shortly after the accident were not submitted to postmortem examination (Chapter VI). In these four there may have been injuries of the category 'other injuries'.

Dencker reported that 23% of the patients had injuries requiring special therapeutic measures. A fracture of the contralateral lower leg existed in 14 (1.4%), the corresponding figure in the present series being 3.3%. Severe craniocerebral injury existed in 27 patients in Dencker's series



local homolateral
associated injuries

	number	%
cerebral concussion	36 (—)	10.9
severe craniocerebral injury	38	11.6
facial fractures	40 (4)	12.1
injury humeroscapular zone	33 (—)	10.0
thoracic injury without resp. disturbances	22 (—)	6.7
thoracic injury with resp. disturbances	12 (—)	3.6
vertebral fracture	3 (—)	1.2
upper arm, elbow injury	19 (1)	5.8
pelvic fracture	22 (—)	6.7
hip injury	4 (0)	1.2
forearm, hand injury	32 (2)	9.7
femoral shaft fracture	6 (1)	1.8
supra-, intracondylar fracture	4 (1)	1.2
knee injury	11 (1)	3.3
lower leg fracture	11 (8)	3.3
ankle, foot injury	8 (1)	2 4
OTHER INJURIES	11 (—)	3.3
ruptured auricle of heart	1	
ruptured spleen	2	
ruptured liver	1	
renal contusion	5	
ruptured bladder	1	
ruptured ascending aorta	1	

Figure 12. General associated injuries. Number of open associated injuries in brackets.

(2.7%), and this is in marked contrast to the 11.6% in the present series.

This study comprises more traffic accident victims than Dencker's series (74% versus 57%). The percentages of accidents on two wheels are virtually the same: 40.3% in Dencker's series and 39.5% in the present series. In the group of accidents sustained while seated in a car, the difference is quite substantial: 7.9% in Dencker's and 25.5% in the present series.

The other comparable series list no pertinent figures.

How to explain the marked difference in the percentage of craniocerebral injuries? Table 23 presents their distribution over the various types of accident.

Table23. Accident types and craniocerebral injury.

accident types	no craniocerebral injury	craniocerebral injury
unknown	3 (75%)	1 (25%)
traffic, on foot	22 (79%)	6 (21%)
traffic, in car	69 (82%)	15 (18%)
traffic, on two wheels	115 (88%)	15 (12%)
work, direct injury	16 (100%)	– (0%)
work, indirect injury	13 (93%)	1 (7%)
home	46 (100%)	– (0%)

It is shown that, of the 38 patients with a severe craniocerebral injury, 36 had been in a traffic accident. A severe craniocerebral injury existed in 21% of patients in the category 'on foot', 18% of those in the category 'in a car', and 12% of those in the category 'on two wheels'.

The difference in the number of severe craniocerebral injuries between Dencker's series and the present series is probably to be ascribed to the larger number of traffic accident victims in the present series, and the larger number of 'in a car' victims among them.

B. LOCAL HOMOLATERAL ASSOCIATED INJURIES:

One or several local homolateral associated injuries existed in 96 patients (29.2%). The distribution over the accident groups is shown in table 24. No local associated injuries were found in the patients who sustained a femoral shaft fracture at home.

Table 24. Accident groups and local associated injuries.

accident groups	no local associated injuries	local associated injuries
traffic	153 (63%)	89 (37%)
work	27 (84%)	5 (16%)
home	46 (100%)	– (0%)

Local associated injuries were significantly more numerous in the group of traffic accident victims than in the group of work accident victims. $\chi_{(1)}^2 = 47.11$ ($p < 0.001$).

Efforts were made to establish the relationship between accident types and the presence of a local associated injury; relevant figures are presented in table 25.

Table 25. Accident types and local associated injuries

accident types	no local associated injuries	local associated injuries
traffic, on foot	17 (61%)	11 (39%)
traffic, in car	54 (64%)	30 (36%)
traffic, on two wheels	82 (63%)	48 (37%)
work, direct injury	7 (100%)	– (0%)
work, indirect injury	9 (64%)	5 (36%)
home	46 (100%)	– (0%)

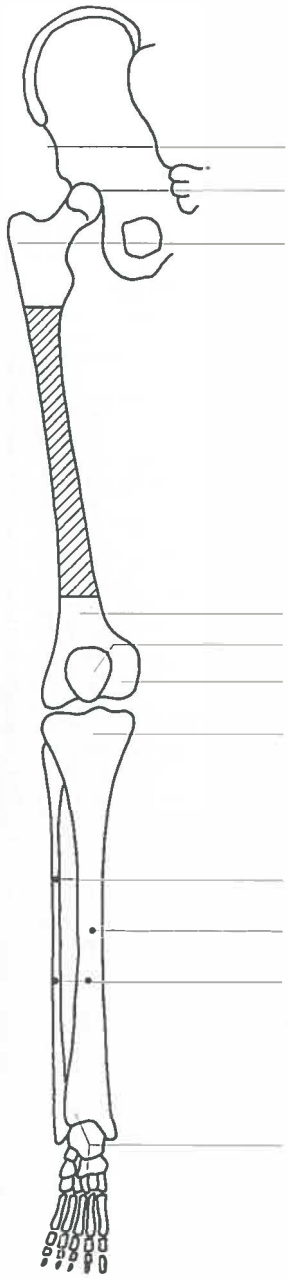
Local injury associated with femoral shaft fracture is found in about one of every three cases in the traffic accident and indirect work injury groups. No local associated injury was found in the direct work injury and the home accident groups.

The local homolateral associated injuries are charted in fig. 13, with the numbers of open fractures presented in brackets.

The percentage of homolateral lower leg fractures (10.9%) invites further consideration. Dencker found a homolateral lower leg fracture in 51 patients (5%). The series from the Mayo Clinic included 11%.

A very conspicuous feature is the large percentage open fractures of the homolateral lower leg fractures in the present series: 72.2%!

Patellar fractures amounted to 5.8%, versus 1.7% reported by Dencker. This difference is



	number	%
hip dislocation	1	0.3
acetabular fracture	5	1.5
femoral neck or pertrochanteric fracture	11	3.4
supra-, intracondylar fracture	4	1.2
patellar fracture	19 (6)	5.8
condylar fracture (medial, lateral)	6	1.8
tibial plateau fracture	7 (2)	2.1
isolated fibular fracture	7 (1)	2.1
isolated tibial fracture	2 (2)	0.6
tibial and fibular fracture	34 (24)	10.3
ankle, foot injury	16 (2)	4.9
OTHER INJURIES		
large wounds	13	4.0
haemarthros of knee	4	1.2
injury to knee ligaments	2	0.6

Figure 13. Local homolateral associated injuries. Number of open homolateral injuries in brackets.

probably to be ascribed to the difference in causative accidents. The present series in particular includes a larger number of car passengers, who in the socalled dashboard injury run a greater risk of sustaining an associated patellar fracture. This subject will be discussed in detail in chapter XII.

IV.6. FRACTURE TYPES

On the basis of the radiographic features, the femoral shaft fractures were divided into a number of fracture types, namely: transverse; oblique; transverse or oblique with butterfly (triangular fragment); spiral; spiral with butterfly; double; and comminuted fractures. It is pointed out again that pathological fractures and fractures due to bullet wound have not been included in this study.

Dencker identified a fracture as transverse if the angle between fracture plane and femoral shaft was 90–65°, and as oblique if this angle was smaller. He further distinguished short oblique (65–45°) and long oblique (< 45°) fractures. His long oblique fractures roughly correspond with the spiral fractures in the present series.

In double fractures there are two unrelated fracture planes.

The comminuted fractures are defined as outlined in Chapter II: the shaft is crushed over a longer distance of its length and there are several fragments of indeterminate shape. Dencker differentiated between 'moderately comminuted' and 'greatly comminuted' – a subdivision not used in the present study. An example of each fracture type used in the present study is presented in figures 14 through 20.

The distribution of the various fracture types is presented in table 26.

The one unclassifiable fracture is a defect fracture sustained in an accident in which a few fragments of the shaft were lost.

Table 26. Distribution of fracture types.

fracture types	number	%
insufficient information	3	0.9
transverse	103	31.3
oblique	35	10.6
transverse or oblique with butterfly	87	26.4
spiral	20	6.1
spiral with butterfly	12	3.6
comminuted	63	19.1
double	5	1.5
unclassifiable	1	0.3

Figure 14. Transverse fracture.

The percentages for transverse and double fractures can be compared with those reported by Dencker, who found 32% and 1%, respectively, versus 31.3% and 1.5% in the present series.

The distribution of the various fracture types over the various accident types is presented in table 27.

Figure 15. Oblique fracture.

Figure 16. Transverse or oblique fracture with triangular fragment.

Figure 17. Spiral fracture.

Figure 18. Spiral fracture with triangular fragment.

Figure 19. Comminuted fracture.

Figure 20. Double fracture.

Table 27. Distribution of fracture types over accident types.*

fracture types	unknown	traffic on foot	traffic in car	traffic on two wheels	work direct	work indirect	sports	home	unclassifiable
transverse		9 9%	23 22%	53 51%	4 4%	4 4%	1 1%	7 7%	2 2%
oblique		3 9%	7 20%	8 23%	2 6%	2 6%	–	13 37%	–
transv./obl. with butterfly	1 1%	8 9%	20 23%	46 53%	3 3%	4 5%	1 1%	2 2%	2 2%
spiral		1 5%	1 5%	1 5%	–	1 5%	–	16 80%	–
spiral with butterfly		–	–	3 25%	1 8%	–	–	8 67%	–
comminuted	1 2%	4 6%	33 52%	15 24%	6 10%	3 5%	–	–	1 2%
double	1 20%	3 60%	–	1 20%	–	–	–	–	–

* The percentual data originate from the computer. They are rounded percentages so that the sum is not always 100.

There is little sense in an effort to establish correlations when the material has been subdivided into so many groups, as indicated in table 27. This is why the fractures were arranged in four major groups. One group encompasses the unclassifiable fractures, those on which insufficient information was available, and the five double fractures. This group will be further left undiscussed. The fracture types of possibly identical causative mechanism were arranged together, and the following groups were thus formed:

a. bending fractures, encompassing transverse, oblique, and transverse or oblique fractures with a butterfly;
b. comminuted fractures;
c. torque fractures, encompassing spiral fractures and spiral fractures with butterfly.

The distribution of the femoral shaft fractures over these groups is repesented in table 28. According to this division about two-thirds of the fractures are fractures in which bending was the principal causative mechanism.

Table 28. Distribution over the fracture groups.

fracture groups	number	%
insufficient information unclassifiable double fractures	9	2.7
bending fractures	225	68.4
comminuted fractures	63	19.1
torque fractures	32	9.7

The numbers in the groups show no even distribution over the sexes. The distribution differs significantly from a proportionate distribution. $\chi_{(2)}^2 = 20.39$ ($p < 0.001$). Particularly the relatively high frequency of spiral fractures in females contributes to this.

The numbers and percentages are listed in table 29.

Table 29. Distribution of fracture groups over the sexes.

fracture groups	males	females
bending fractures	171 76%	54 24%
comminuted fractures	59 94%	4 6%
torque fractures	17 53%	15 47%

The distribution over the accident groups is shown in table 30.
The distribution is not even, but shows significant differences. $\chi_{(4)}^2 = 108.48$ ($p < 0.001$). The large number of torque fractures sustained at

Table 30. Distribution of fracture groups over accident groups.

fracture groups	traffic	work	home
bending fractures	177 80%	21 10%	22 10%
comminuted fractures	52 85%	9 15%	–
torque fractures	6 19%	2 6%	24 75%

home particularly contributes to this. It is to be noted that the test result should be regarded with some reservation because one of the expected values is smaller than 5.

In the aetiology of torque fractures, a pre-existent pathology of the hip-joint would seem to be important. The 18 patients with hip-joint disease or a history of medial femoral neck fracture included 13 whose femoral shaft fracture was a torque fracture. The pertinent data are presented in table 31.

Table 31. Fracture groups and hip-joint disease.

fracture groups	no hip-joint disease	hip-joint disease
bending fractures / comminuted fractures	283 (98.3%)	5 (1.7%)
torque fractures	19 (59.4%)	13 (40.6%)

The distribution differs significantly. $\chi_{(2)}^2 = 82.05$ ($p < 0.001$). A major contribution to this significant difference is made by the large number of torque fractures in patients with preexistent hip-joint disease. One of the expected values is smaller than 5, and the result should consequently be regarded with some reservation.

Comminuted fractures had to be studied in order to find support for the hypothesis, advanced in Chapter II, concerning the factors of importance in the aetiology of these fractures: direct impingement of violence and/or a large amount of energy involved.

Direct impingement of violence plays a role in femoral shaft fractures sustained as direct injury in the work situation (table 27). Of the 16 fractures in this category, 6 were comminuted. The accident details give an impression of the mechanism involved in these six cases:

* thigh incarcerated between two lorries;
* stack of steel plates falling on the thigh (contralateral femur also sustained comminuted fracture: eliminated by lot);
* leg under heavy roll of paper;
* slab of slate falling on leg;
* forklift-truck rolling across thigh;
* lever kicking back with great force against thigh.

The factor 'high energy' can also be studied from table 27.

Traffic accidents caused 85% of the comminuted fractures, and the majority of these accidents were car crashes. The pertinent data are presented in table 32.

Table 32. Traffic accidents and comminuted fractures.

traffic accidents	total number of fractures	number of comminuted fractures
on foot	28	4 (14.3%)
in car	84	33 (39.2%)
on two wheels	130	15 (11.5%)

It may be assumed that, of the traffic accidents, car crashes as a rule involve the largest amount of energy.

Open and closed fractures are not evenly distributed over the fracture groups. There is a significant difference. $\chi_{(2)}^2 = 20.31$ ($p < 0.01$). Numbers and percentages are given in table 33.

Table 33. Fracture groups and open fractures.

fracture groups	closed	open
bending fractures	197 (89%)	25 (11%)
comminuted fractures	43 (68%)	20 (32%)
torque fractures	31 (97%)	1 (3%)

The largest percentage of open fractures was found among the comminuted fractures.

IV.7. DISTRIBUTION OVER THE SHAFT

The shaft of the femur, defined as indicated in Chapter II, was divided into seven equal segments, numbered 1 through 7 from the cranial to the caudal end. This was done with a view to the consequences of the fracture site for the choice of treatment. The need was felt to demarcate a small subtrochanteric area because fractures in this area pose their own particular problems.

Segments 2 and 3 together form what is otherwise known as proximal one-third of the femoral

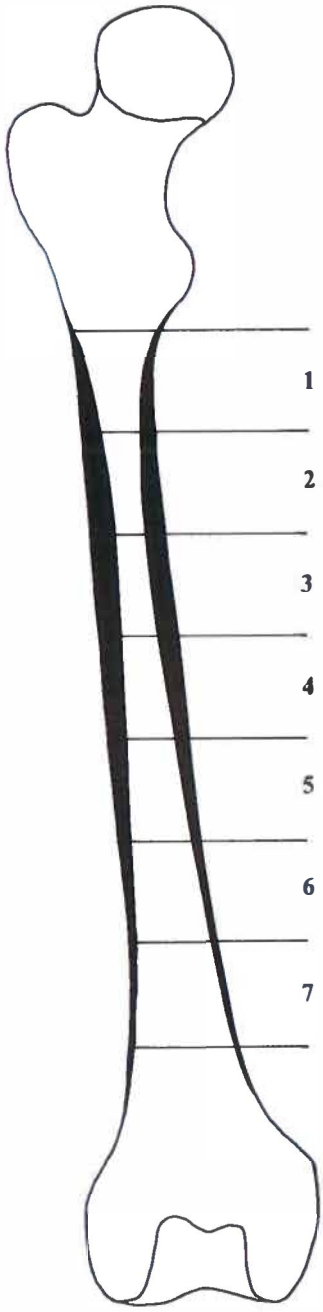


Figure 21. Division of the femoral shaft into seven equal segments.

shaft; segments 4 and 5 together are also known as middle one-third, and segments 6 and 7 as distal one-third. The divisions of the femoral shaft are shown in fig. 21.

The segments involved in each fracture were noted. Each time that one of the segments was involved in a fracture this was counted as such. Three fractures on which insufficient information was available were eliminated. The degree of involvement of each segment in the total number of fractures is indicated in fig. 22.

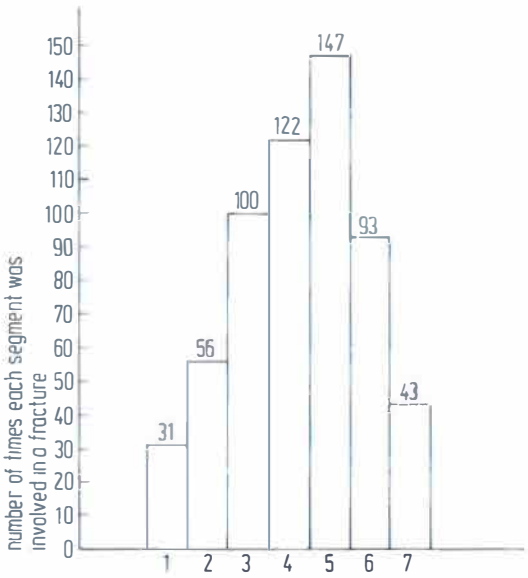


Figure 22. Histogram showing how many times each shaft segment was involved in a fracture.

It can be deduced from fig. 22 that in particular the so-called 'middle one-third' (segments 4 and 5) is most frequently involved. In this portion of the shaft the medullary cavity widens again distal to the isthmus. Histograms of this kind were made for several fracture types and are presented in figures 23 through 27.

Fig. 28, finally, shows the distribution of the bending fractures over the shaft.

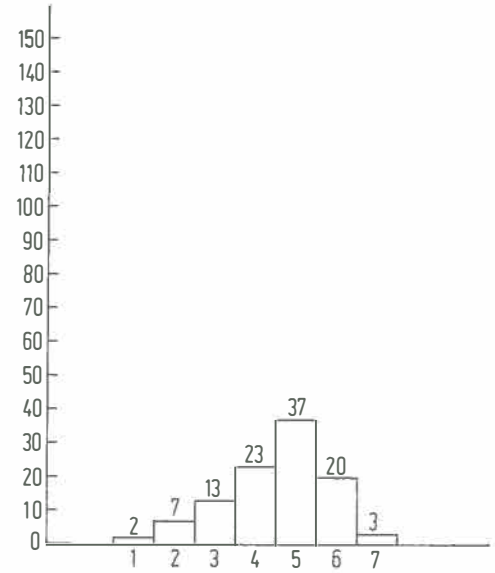


Figure 23. Distribution of transverse fractures over the shaft.

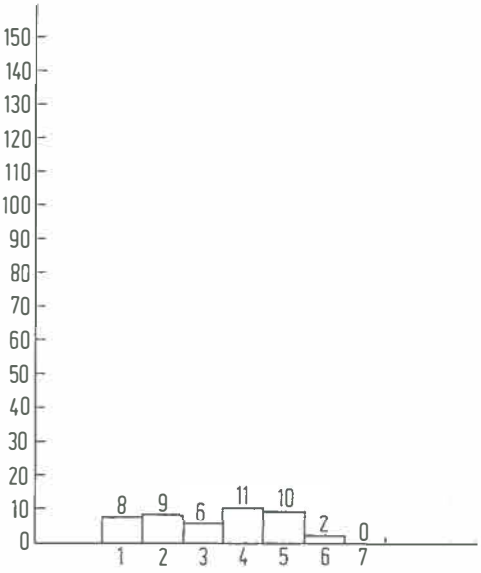


Figure 25. Distribution of oblique fractures over the shaft.

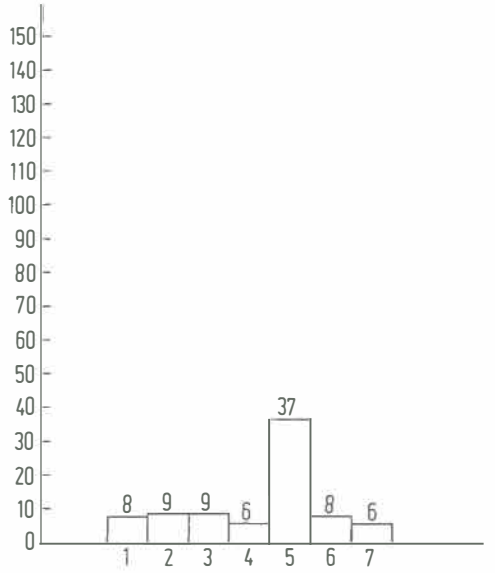


Figure 24. Distribution of spiral fractures over the shaft.

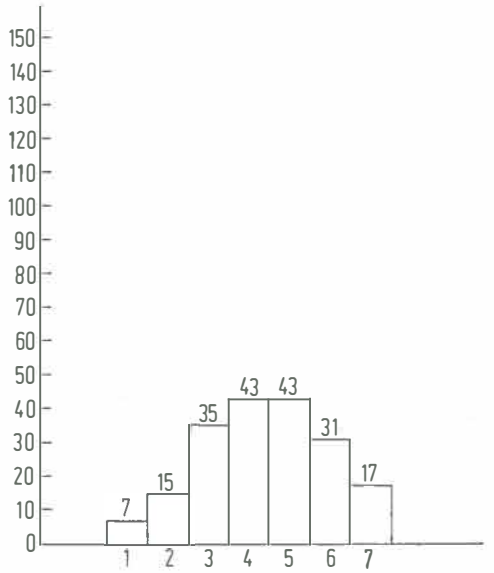


Figure 26. Distribution of comminuted fractures over the shaft.

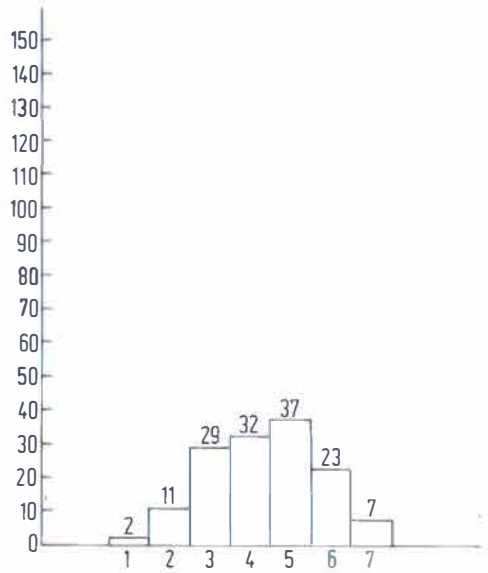


Figure 27. Distribution of transverse or oblique fractures with butterfly over the shaft.

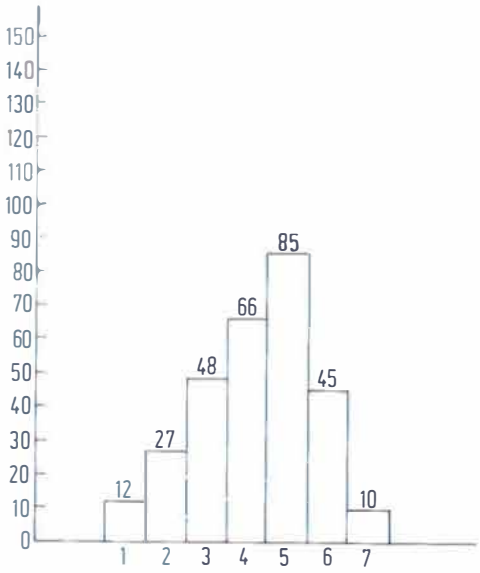


Figure 28. Distribution of bending fractures over the shaft.

IV.8. SUMMARY

This chapter charts the femoral shaft fracture in adults, elucidating all its features. A survey of comparable series is presented, and the data from these series are compared whenever possible with the present series.

The incidence per decade per 1000 adult population was calculated. There are considerable differences between the sexes. Femoral shaft fractures are most frequently seen in young males and aged females. While in males the frequency of femoral shaft fractures gradually diminishes with increasing age, females show a marked increase in frequency after age 50. This increase is probably due to increased fragility of the bone due to osteoporosis resulting from menopausal hormonal changes.

The group of patients aged 70 or over shows a female predominance, whereas the groups of patients under 70 show a male predominance.

As expected, aged patients showed a higher incidence of preexistent disease than young patients.

Traffic accidents are responsible for some three-quarters of all femoral shaft fractures, the remaining fractures having occurred in the work situation and in accidents at home. Accidents at home mostly involved the aged patients.

This series includes more fractures of the left than of the right femur, but the difference is not significant.

Traffic accidents and work accidents show a significant difference in laterallity in that the former more frequently involve the left and the latter more frequently the right femur. The left-right distribution in this series differs significantly from that in Dencker's series, the difference probably being due to the fact that traffic kept to different sides of the road at the time in the countries where the fractures occurred.

Generally speaking, one out of every seven femoral shaft fractures is an open fracture. Fractures sustained in accidents at home are rarely open fractures.

Some numerical data are presented on patients in shock and with alcohol intoxication.

General and local associated injuries were frequently found. General associated injuries existed in more than half of the traffic accident victims, and in as many as 77% of those sustaining a femoral shaft fracture while seated in a car. Accidents at home rarely cause general associated injuries. Severe craniocerebral injury occurred in 11.6% of patients, mostly traffic accident victims.

Local associated injuries occurred in over 33% of patients who were in a traffic accident or sustained an indirect injury at work. In more than 10% of all patients there was a homolateral lower leg fracture (which was an open fracture in some 75% of these cases).

Different fracture types are distinguished. Transverse fractures were involved in nearly one-third of cases, and comminuted fractures in nearly 20%. The fracture types were arranged in three major groups: bending fractures, comminuted fractures and torque fractures. Torque fractures occurred mostly in women who sustained a fall at home. Pre-existent hip-joint disease was often noted in spiral fractures of the femoral shaft. There are indications that comminuted fractures are most likely to be due to direct impingement of violence and to accidents involving a large amount of energy.

Torque fractures are rarely open, but comminuted fractures are open in more than one-third of cases.

After dividing the femoral shaft into seven segments numbered 1 through 7 from the cranial to the caudal end, it was found that segments 4 and 5 were most often involved in femoral shaft fractures. In this portion of the shaft the medullary cavity widens, immediately distal to the isthmus. Fractures involving this portion are mostly bending fractures.

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Chapter V
The methods of treatment

V.1. INTRODUCTION

The treatment of a patient with a femoral shaft fracture should be focused primarily on saving life, next on saving the limb, and finally on optimal anatomical and functional restoration of the limb. The method of treatment is a means to achieve this. The value of this means can be measured from the result obtained, but it is to be borne in mind that the end-result is determined, not only by the method of treatment but also by the nature and extent of the injury, and by the nature of the patient.

The classical rules of fracture management are: reduction, immobilization and active exercise. In the management of femoral shaft fractures these therapeutic activities can be performed in different ways. Reduction, for example, can be effected by an open or by a closed procedure. If after closed reduction the apposition of fragments is maintained by skeletal traction and/or by means of a splint, then treatment is described as conservative. In that case restoration of function must wait until bony union has occurred, unless use is made of socalled balanced suspension traction (more about this in section V.2.).

Operative treatment consists of open reduction and, if necessary, internal fixation. The latter can be achieved in several different ways. A widely used method is intramedullary nailing according to Küntscher. Compression plate osteosynthesis has superseded such methods as plating according to Lane, plating according to Eggers, dual plating etc. Less widely used methods in the fixation of femoral shaft fractures are nailing according to Rush, wire cerclage, fixation by means of screws, and the 'fixateur externe'.

In the Groningen University Surgical Clinic, femoral shaft fractures were treated in several different ways during the period 1958 through 1969. A survey of the methods of treatment used during the period studied is presented in fig. 29.

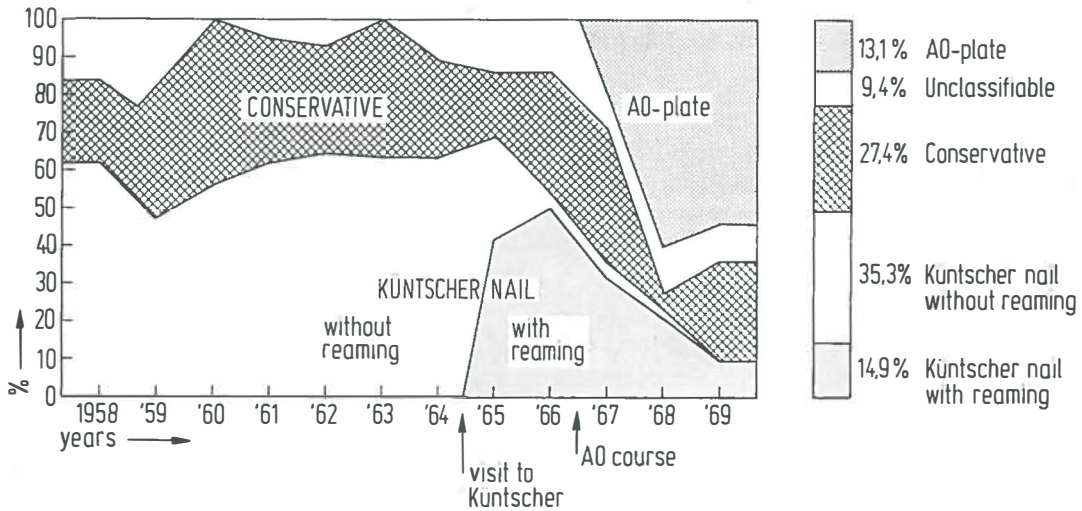

Figure 29. Schematic survey of the methods of treatment used during the period 1958 through 1969.

Some 50% of patients were treated by Küntscher nailing; some 25% received conservative treatment, and some 13% were treated by A.O.-plate osteosynthesis; other methods were used in the remaining cases. In the final analysis, therefore, four methods of treatment were used side by side:

1. conservative treatment;
2. Küntscher nail osteosynthesis without reaming of the medullary cavity;
3. Küntscher nail osteosynthesis with reaming of the medullary cavity;
4. A.O.-plate osteosynthesis.

That so many different methods of treatment were used during the period studied results from the fact that the Clinic is a teaching clinic as well as a department of a large general hospital. Because it is a teaching clinic, several methods of treatment were used side by side for didactic purposes.

Two new developments in osteosynthesis can be encountered and assessed in this series. They are: the reaming of the medullary cavity in Küntscher nailing, and the use of the A.O.-compression plate. Both new methods of treatment were introduced in the Groningen University Surgical Clinic after study tours made by the head of the Department of Traumatology (B. Binnendijk, M.D.), who in December 1964 visited Küntscher's clinic and in December 1966 attended the A.O. course in Davos.

Figure 29 clearly shows the influence of these tours on the choice of method in treating femoral shaft fractures.

The fact that several methods of treatment were used side by side in this series makes it possible to compare these methods. In this study an attempt will be made to evaluate these methods of treatment on the basis of four criteria:

* duration of bony union;
* complications;
* anatomical and functional restoration;
* socio-economic aspects.

The four methods of treatment used will be compared on the basis of these four criteria, but first they will be described in detail as they were applied to the femoral shaft fractures in this series.

V.2. CONSERVATIVE TREATMENT

Conservative treatment generally consisted of skeletal traction and some form of splinting. Skeletal traction was initially applied by means of a wire passed through the supracondylar region of the femur. In subsequent years the wire was passed through the tibial tuberosity. The leg was placed on a Braun splint and in some cases a supporting plaster bandage was applied. The clinical appearance of the limb was taken into account.

The position of the fracture and the progress towards bony union were assessed on the basis of radiographs obtained at regular intervals. Axial deformities were corrected by changing the direction of traction and with the aid of pillows or bands. Reduction was sometimes effected under general anaesthesia.

When it was assumed that dislocation could no longer occur, a plaster spica was initially used. In later years, more frequent use was made of balanced suspension traction (Wijnen 1929; Kuijjer et al. 1963; Kingma and Rogge 1973) The advantage of balanced suspension traction in conservative fracture treatment is that functional restoration can be started earlier.

A number of patients were transferred to a nursing-home before they were allowed to return to their homes.

After clinical treatment, follow-ups were made at regular intervals in the out-patient clinic until the end-result was achieved or could be expected shortly to be achieved.

The rehabilitation department participated in the management of these cases from the start.

V.3. KÜNTSCHER NAIL OSTEOSYNTHESIS

Until 1965, Küntscher nail osteosynthesis was always carried out in the same way. The fracture was exposed by the direct lateral approach. From the fracture site a guide wire was inserted in cranial direction. The guide wire was then traced via a separate incision. The fracture was reduced

whereupon a Küntscher nail was inserted over the guide wire. The nail was so chosen that its diameter did not exceed that of the narrowest part of the isthmus. This was estimated from a radiograph of the intact femur. The nails used were of the cloverleaf type in cross-section; the largest nail diameter was 10 mm. After the operation the leg was placed on a Braun splint, sometimes supported by a plaster bandage.

After wound healing the patient was discharged (if the other injuries permitted this), sometimes with a plaster spica.

From 1965 on the medullary cavity was reamed out, and the Küntscher nail was often inserted by a closed method. The 62 Küntscher nail osteosyntheses since performed involved reaming of the medullary cavity in 49 patients, in 35 of whom the nail was inserted by a closed procedure.

Open Küntscher nail osteosynthesis with reaming of the medullary cavity was performed by a procedure which differed on two points from Küntscher nailing without reaming. The approach was made by the indirect lateral route, the medullary cavity then being reamed by means of flexible drills inserted over a guide wire. The Küntscher nail inserted had a diameter which was 0.5–1 mm less than that of the last used drill.

Closed Küntscher nail osteosynthesis was carried out in the manner described by Küntscher himself (1962, 1967). The patient was placed on an extension table in a lateral recumbent position, with the fractured femur freely accessible all round to an image intensifier. A Steinmann nail was introduced into the supracondylar region, and traction was exerted on this nail. The trochanter was traced via an incision proximal to the greater trochanter. The guide wire was inserted into the medullary cavity, whereupon reduction was effected under fluoroscopic control. The rotation of the distal fragment was estimated visually. After reduction the guide wire was advanced, whereupon reaming of the medullary cavity began. Once the medullary cavity was reamed to a sufficient diameter, a Küntscher nail was inserted which was 0.5–1 mm less in diameter.

The criterion for sufficient reaming, in the open as well as in the closed procedure, was that the nail could be expected to find an adequate hold proximal and distal to the fracture.

An attempt at closed reduction was occasionally unsuccessful, in which case the procedure was changed to open reduction. A Redon drain was left and the wound (or wounds) was (were) closed in layers.

When complete stability was attained, the leg was placed on a Braun splint during wound healing. After 1–2 weeks the patient was allowed to move the leg freely and to walk on crutches without weight-bearing. If no complete stability was attained, a Braun splint or a swinging extension bandage was applied until bony union had occurred.

A number of patients were transferred to a nursing-home before they were allowed to return to their own homes.

Regular follow-ups were made in the outpatient clinic until the end-result was achieved or was expected shortly to be achieved.

In this study, patients treated by Küntscher nail osteosynthesis are divided into two groups:

1. Küntscher nail osteosynthesis without reaming of the medullary cavity;
2. Küntscher nail osteosynthesis with reaming of the medullary cavity.

The comparability of these groups will be discussed in section V.6.

V.4. A.O.-PLATE OSTEOSYNTHESIS

Compression plate osteosynthesis according to the A.O. came into use towards the end of the period studied. During 1968 and 1969, this method was used in slightly more than 50% of the patients treated (fig. 29). The technique as described by the A.O. was carefully applied (Müller et al. 1965).

The fracture was exposed by the posterolateral approach. Efforts were made to ensure anatomical reduction. A detached fragment, if present, was fixed to one of the main fragments by means of lag screws. A plate of stainless steel was so shaped as to fit well against the lateral aspect of the bone. It was fixed to the femur by means of screws, while the main fragments were pressed together. Sometimes, a few of the screws used to fix the plate were at the same time used as lag screws to fix a fragment.

Very proximal or distal fractures were fixed with the aid of an angle plate or a 130° plate, in accordance with the A.O. recommendations.

After introduction of a Redon drain the wound was closed in layers.

After the operation the limb was placed on a splint; fixation was stable as a rule, so that exercise could be started after a few days.

The patient was discharged home or transferred to a nursing-home. During the first months following osteosynthesis, non-weightbearing walking on crutches was not permitted in order to prevent the patient from becoming too confident of the firmness of the plate. Follow-ups were made in the out-patient clinic in the same manner as with the other methods of treatment.

V.5. THE 'UNCLASSIFIABLE' GROUP

In 31 patients the method of treatment used could not be brought under any of the headings of the four methods of treatment defined in section V.1. On the basis of the reasons for unclassifiability, these patients can be divided into the following categories:

a. Death before a given method of treatment could be started (14 patients).
b. Use of various other techniques of osteosynthesis (7 patients).
c. Primary amputation (2 patients).
d. Atypical method of treatment (8 patients).

re a. Death occurred before any treatment of the femoral shaft fracture could be started in 14 cases. Further details are given in Chapter VI which discusses the mortality. Obviously, these patients cannot be included in an assessment of the results of the various methods of treatment.

re b. In the treatment of 7 patients, other techniques of osteosynthesis were used. The group is too small and too heterogenous to be considered as a separate group in the design of this study. The various techniques of osteosynthesis used were: plating according to Lane: 5, screw osteosynthesis: 1, and nail and plate according to McLaughlin: 1.

re c. A primary amputation was performed in 2 patients. In one patient (nr. 334) a circular lesion of the thigh and comminution of the homolateral knee and lower leg necessitated amputation on the day of the accident. In the other patient (nr. 304), deep circular burns of the thigh necessitated amputation six days after the accident, in which burns of 45% of the body surface were sustained.

re d. An atypical method of treatment was used in 8 patients. In one patient (nr. 097) a defect fracture was treated by repair of the defect with the aid of an autogenous fibular graft. In one patient (nr. 277) a lesion of the patellar ligament was not identified until after three months of conservative treatment, which was then discontinued in favour of a plate osteosynthesis. The tendon was subsequently repaired in another hospital.

In three patients (nrs. 006, 179 and 258) a callus fracture during conservative treatment was treated by osteosynthesis. These patients will be discussed in the chapter on complications.

In three other patients (nrs. 257, 264 and 295) conservative treatment was discontinued 3–5 months after the accident, and A.O.-plate osteosynthesis was performed. In these patients the natural course of conservative treatment was influenced by an operative intervention, and these patients are therefore representative neither of the conservative nor of the operative treatment. Whether non-union of a fracture after 5 months of conservative treatment is as such a complication will be discussed in the chapter on complications (Chapter VIII).

V.6. COMPARABILITY OF METHODS OF TREATMENT

The frequency and the distribution of the methods of treatment is presented in table 34.

The various methods of treatment were tested for comparability in terms of the distribution over:

* sexes
* age groups
* pre-existent diseases
* accident groups
* presence of general associated injuries
* presence of craniocerebral injury
* presence of local associated injuries
* presence of homolateral lower leg fracture

* open or closed fracture
* fracture groups
* shaft segment fractured
* antibiotic medication
* prophylactic anticoagulant medication

Significant differences were found in distribution over fracture types, shaft segment involved, antibiotic medication and prophylactic anticoagulant medication. The relevant data are presented in tables 35 through 46.

Table 34. Distribution over methods of treatment.

Methods of treatment	Number	Percentage
conservative	90	30.2%
Küntscher nail without	116	38.9%
Küntscher nail with	49	16.4%
A.O.-plate	43	14.4%

Table 35. Methods of treatment and sex.

Methods of treatment	males	females
conservative	64 (71%)	26 (29%)
Küntscher nail without	96 (83%)	20 (17%)
Küntscher nail with	38 (78%)	11 (22%)
A.O.-plate	34 (79%)	9 (21%)

$\chi_{(3)}^2 = 4.03$
not significant

Table 36. Methods of treatment and age groups.

Methods of treatment	age groups 17–19	20–29	30–39	40–49	50–59	60–69	70 and over
conservative	10 (11%)	17 (19%)	11 (12%)	6 (7%)	15 (17%)	13 (14%)	18 (20%)
Küntscher nail without	16 (14%)	28 (24%)	15 (13%)	16 (14%)	15 (13%)	13 (11%)	13 (11%)
Küntscher nail with	8 (16%)	13 (27%)	7 (14%)	7 (14%)	4 (8%)	7 (14%)	3 (6%)
A.O.-plate	7 (16%)	13 (30%)	4 (9%)	6 (14%)	4 (9%)	3 (7%)	6 (14%)

$\chi_{(18)}^2 = 15.23$
not significant

Table 37. Methods of treatment and accident groups.

Methods of treatment	accident groups traffic	work	home
conservative	59 (66%)	11 (12%)	19 (21%)
Küntscher nail without	88 (78%)	13 (12%)	12 (11%)
Küntscher nail with	42 (86%)	3 (6%)	4 (8%)
A.O.-plate	31 (76%)	4 (10%)	6 (15%)

$\chi_{(6)}^2 = 8.60$
not significant

Table 38. Methods of treatment and pre-existent diseases.

Methods of treatment	no pre-existent disease	pre-existent disease
conservative	61 (68%)	29 (32%)
Küntscher nail without	85 (73%)	31 (27%)
Küntscher nail with	39 (80%)	10 (20%)
A.O.-plate	26 (60%)	17 (40%)

$\chi_{(3)}^2 = 4.79$
not significant

Table 39. Methods of treatment and general associated injuries.

Methods of treatment	no general associated injuries	general associated injuries
conservative	46 (51%)	44 (49%)
Küntscher nail without	71 (61%)	45 (39%)
Küntscher nail with	25 (51%)	24 (49%)
A.O.-plate	23 (53%)	20 (47%)

$\chi_{(3)}^2 = 2.69$
not significant

Table 40. Methods of treatment and craniocerebral injury.

Methods of treatment	no craniocerebral injury	cranio-cerebral injury
conservative	80 (89%)	10 (11%)
Küntscher nail without	108 (93%)	8 (7%)
Küntscher nail with	43 (88%)	6 (12%)
A.O.-plate	37 (86%)	6 (14%)

χ^2 not calculated: expected numbers too small.

Table 41. Methods of treatment and local associated injuries.

Methods of treatment	no local associated injuries	local associated injuries
conservative	65 (72%)	25 (28%)
Küntscher nail without	82 (71%)	24 (29%)
Küntscher nail with	36 (73%)	13 (27%)
A.O.-plate	30 (70%)	13 (30%)

$\chi_{(3)}^2 = 0.21$
not significant

Table 42. Methods of treatment and homolateral lower leg fracture.

Methods of treatment	no homolateral lower leg fracture	homolateral lower leg fracture
conservative	80 (89%)	10 (11%)
Küntscher nail without	108 (93%)	8 (7%)
Küntscher nail with	43 (88%)	6 (12%)
A.O.-plate	38 (88%)	5 (12%)

χ^2 not calculated: expected numbers too small.

Table 43. Methods of treatment and closed or open fracture.

Methods of treatment	closed	open
conservative	77 (86%)	13 (14%)
Küntscher nail without	97 (86%)	16 (14%)
Küntscher nail with	43 (88%)	6 (12%)
A.O.-plate	37 (86%)	6 (14%)

$\chi_{(3)}^2 = 0.14$
not significant

Table 44. Methods of treatment and fracture types.

Methods of treatment	fracture types bending	comminuted	torque
conservative	42 (47%)	32 (36%)	15 (17%)
Küntscher nail without	91 (81%)	15 (13%)	6 (5%)
Küntscher nail with	46 (96%)	1 (2%)	1 (2%)
A.O.-plate	28 (65%)	9 (21%)	6 (14%)

$\chi_{(6)}^2 = 45.81$
significant ($p < 0.001$)

Since the fracture groups are differently distributed over the shaft, there is also a significant difference in the distribution of methods of treatment over the shaft segments. Data in this respect are not relevant and not presented here.

Table 45. Methods of treatment and antibiotic medication.

Methods of treatment	no antibiotic medication	antibiotic medication
conservative	40 (47%)	46 (53%)
Küntscher nail without	18 (16%)	97 (84%)
Küntscher nail with	15 (31%)	34 (69%)
A.O.-plate	22 (51%)	21 (49%)

$\chi_{(3)}^2 = 29.51$
significant ($p < 0.01$)

The distribution over patients who did and patients who did not receive antibiotics, differs significantly from an even distribution.

This is due in particular to the large number of patients in whom Küntscher nail osteosynthesis without reaming of the medullary cavity was

accompanied by antibiotic medication. This is a result of the policy followed concerning antibiotic medication. Initially, antibiotics were prophylactically given in every case of operative fracture treatment; in 1965 this policy was modified, and antibiotics were restricted to open fractures and cases in which they were considered necessary in view of other injuries or affections. Operative fracture treatment as such was not accepted as an indication for antibiotics. The fact that, up to 1965, over 50% of patients were treated by Küntscher nail osteosynthesis without reaming of the medullary cavity, explains why so large a percentage of patients given antibiotics is found under the heading of this method of treatment. The distribution of patients who did and patients who did not receive prophylactic anticoagulant medication differs significantly from an even distribution over the methods of treatment. The question is whether these differences in terms of antibiotic and anticoagulant mediation are relevant with regard to the criteria to be used in comparing the four methods of treatment.

The distribution over patients with a homolateral lower leg fracture and those with a cranio-cerebral injury cannot be submitted to the Chi-square test because the expected numbers are too small. On the basis of the percentages it can be assumed that there are no very pronounced differences.

Table 46. Methods of treatment and prophylatic anticoagulant medication.

Methods of treatment	no prophylactic anticoagulant medication		prophylactic anticoagulant medication	
conservative	41	(48%)	44	(52%)
Küntscher nail without	78	(68%)	37	(32%)
Küntscher nail with	28	(57%)	21	(43%)
A.O.-plate	22	(51%)	21	(49%)

$\chi_{(3)}^2 = 8.71$
significant ($p < 0.05$)

In view of the above it seems justifiable to describe the four methods of treatment in this series as comparable, with the restriction that certain fracture types were better suited to certain methods of treatment.

V.7. SUMMARY

This chapter discusses the manner in which the femoral shaft fractures in this series were treated. Four different methods of treatment were distinguished, namely: conservative treatment, Küntscher nail osteosynthesis without, and with reaming of the medullary cavity, and A.O.-plate osteosynthesis. The various methods of treatment were used at random; only with regard to fracture type and with regard to shaft segment involved are there differences. These differences result from differences in the range of indications for the various methods of treatment. There is a difference also with regard to antibiotic and anticoagulant medication, but the question is whether these differences are of relevance with regard to the criteria to be used in comparing the four methods of treatment.

V.8. REFERENCES

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Chapter VI
Mortality

VI.1. INTRODUCTION

It has been stated in Chapter I that a patient with a femoral shaft fracture runs a number of risks. This chapter considers the risk of dying.

The femoral shaft fracture as such will rarely be the direct cause of death. It is often the severe associated injuries that lead to a fatal issue. In the context of this study, only the causes of death will be mentioned so far as fatalities of this category are concerned. Attention will be focused instead on general fatal complications and those which specifically correlate with the type of treatment used. In the lastmentioned group, a fatal issue might possibly have been avoided if a different treatment had been chosen. For example, a fatal sepsis originating from an infected osteosynthesis might not have developed if some non-operative form of treatment had been used. On the other hand, a decubitus leading to a fatal issue might have been avoided if osteosynthesis had allowed early ambulation.

Some fatal complications are known to have been reported in the early days of Küntscher nail osteosynthesis. Most of these reports concerned irreversible shock (Böhler 1948). Fatal fat embolisms and a case of fatal air embolism have also been ascribed to Küntscher nailing (Lauritzen 1949; Lécutier and Smith 1957). In later publications (e.g. Rokkanen et al. 1969) these complications are no longer mentioned.

The number of deceased patients in the present series is small, and the variables involved are numerous. Statistical analysis of the data of the deceased patients would therefore not be meaningful.

VI.2. DEATH RATE

Of the 329 patients with a unilateral or bilateral femoral shaft fracture, 24 died in hospital, all within six months of the accident. Another 5 patients died in nursing-homes, likewise within six months. These 5 patients were included in calculating the hospital mortality because management in a nursing home is a continuation of hospital management.

The hospital mortality in this series is 8.8%. If the series is divided into two equal halves – patients nr. 001 through nr. 172, and patients nr. 173 through nr. 338 – then the respective death rates are 7.3% and 10.3%. The respective death rates for the first and the second six-year term of the period studied are 6.6% and 10.4%. Dencker reported a hospital mortality of 9.5%. The death rate in the series of Buck-Gramcko was 10.6%.

The relevant data on the 29 deceased patients are presented in table 47.

Severe craniocerebral injury caused the deaths of 11 patients shortly after the accident, and of 2 patients a few months later. Severe thoracic injury contributed to the cause of death in 7 patients, 5 of whom were also listed under the heading 'death due to severe craniocerebral injury'. The other 2 patients with a severe thoracic injury respectively died from haemorrhage from the short gastric veins following splenectomy and from circulatory insufficiency on the basis of myocardial infarction sustained prior to the accident.

Table 47. Survey of deceased patients.

	deceased in hospital											
patient number	002	004	008	028	070	089	101	141	149	162	181	192 193
age at accident	67	21	93	88	84	90	50	90	61	91	82	72
sex	f	m	m	m	m	f	f	m	m	m	m	f
days until death	182	3	3	1	15	50	3	14	6	2	12	53
accident injuries:												
severe craniocerebral injury	+	+							+			+
chest injury with resp. dist.							+		+			+
blunt abdominal injury							+					
pre-existent diseases					+			+				
treatment*	K	N	N	N	N	C	N	K	K	N	N	K K
complications:												
bronchopneumonia	+				+	+					+	+
pulmonary embolism												
pyelonephritis												
fat embolism	+	+	+	+						+	+	
cerebrovascular accident				+								
cardiac arrest				+				+				
'deep' infection	+											
postmortem	+	–	+	+	+	+	+	–	+	+	+	+

* abbreviations used for methods of treatment: N = no treatment
C = conservative treatment
K = Küntscher nail osteosynthesis
AO = AO-plate osteosynthesis
D = various other techniques of osteosynthesis

The 9 patients whose deaths were due neither to severe craniocerebral injury nor to severe thoracic injury, included 5 who died from bronchopneumonia, 2 who died from fat embolism, and 2 who died from 'cardiac arrest'. One of the last-mentioned two patients had had a cerebral haemorrhage shortly before death, and the other patient had suffered from severe cardiac failure prior to the accident.

Two patients therefore died as a direct result of fat embolism, which contributed to the deaths of 5 other patients. The relationship between fat embolism and femoral shaft fracture will be discussed in some detail in a separate section of Chapter XII.

All patients who died in a nursing-home following discharge from hospital were far advanced in years. The exact cause of death in these cases cannot be traced. Four had pre-existent diseases. Three had shown increasing dementia, urinary incontinence and decubitus while in hospital.

The number of deceased patients per age group is shown in fig. 30. Of the 6 patients aged 90 and over at the time of the accident, 5 died within six months!

Examination of fig. 30 discloses that all deceased patients under 70 (except one) had sustained a severe craniocerebral injury, whereas patients over 70 as a rule died from other causes.

The death rate per age group is presented in fig. 31. The death rate for the group 70 and over is 32.6 %; this means that one out of every three patients aged 70 or over at the time of the accident, died within six months!

										deceased in nursing-home				
223	235	253	292	296	297	305	307	325	332	078	110	189	199	299
25 m 7	19 m 8	34 m 81	74 f 10	90 f 22	56 m 10	44 m 1	25 m 4	83 f 48	19 m 2	85 f 86	77 m 165	81 m 81	86 f 64	73 f 160
+	+	+			+	+	+		+					
			+		+	+								
			+											
			+		+			+			+	+	+	+
N	N	C	N	AO	AO	AO	N	AO	N	K	C	D	K	AO
				+										
		+		+										
				+			+							
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		+												
+	+	+	−	+	+	+	−	−	−	−	−	−	−	−

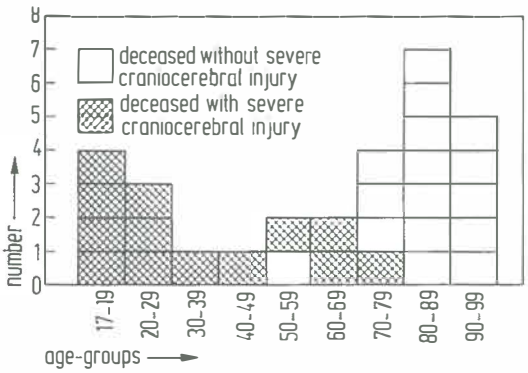

Figure 30. Number of deceased per age group, differentiating between those with and those without severe craniocerebral injury.

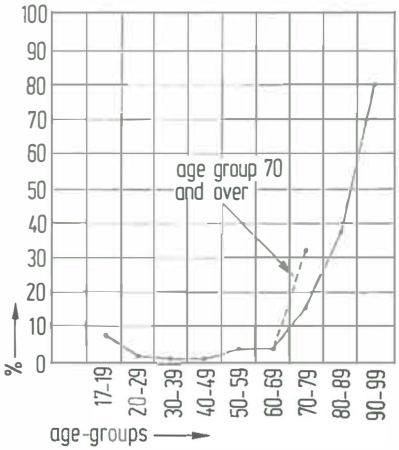

Figure 31 Death rate per age group.

VI.3. DECEASED PATIENTS

Efforts must be made to establish a possible relationship between the fatal issue and the treatment of the femoral shaft fracture. It is conceivable, after all, that a patient who died from bronchopneumonia during conservative treatment, might not have developed bronchopneumonia if submitted to more aggressive treatment aimed at early ambulation.

On the other hand it is conceivable that a patient dies from a complication following an operation intended to spare him the ordeal of prolonged immobilization. Again, the opposite of the desired effect is so achieved.

Table 47 lists 14 patients as having received no treatment (N). These patients died within two weeks of the accident. A tibial tuberosity wire extension had been applied but this was considered to have been of too short duration to be representative of conservative treatment. In the same situation, patients who had been submitted to an operation had of course received some sort of treatment, but its effect had remained uncertain due to the intervening death. But in these cases treatment should be mentioned as such, because the death may have been a direct result of that particular treatment.

Table 48 shows the number of deaths in relation to methods of treatment. This table also includes deaths which occurred in a nursing-home.

Table 48. Methods of treatment and number of deaths.

Method of treatment	number of deaths
none	14
extension	3
Küntscher nailing	6
A.O.-plate osteosynthesis	5
various other techniques of osteosynthesis	1
total	29

The case histories of the patients who received a given method of treatment will now be presented and discussed.

Deceased patients given conservative treatment:

1. Patient nr. 253, a man aged 34, crashed his motorcycle in a collision with a car and sustained a contusion of the brain, fracture of the nasal bone, multiple facial wounds and a closed transverse femoral shaft fracture. A tibial tuberosity wire extension was applied and a tracheotomy performed. Patient was comatose and showed urinary and faecal incontinence. The indwelling catheter caused a urinary infection (Proteus mirabilis). The patient was restless, and 18 days after the accident the fracture haematoma ruptured; Proteus mirabilis was cultured from the haematoma fluid five days later.

Various antibiotics were given in large doses. An abscess formed at the fracture site. This was drained. Aerobacter aerogenes sepsis developed six weeks after the accident. Staphylococcus aureus was isolated from the abscess discharge. A few weeks later, septic shock led to the patient's death.

Postmortem: posttraumatic cerebral atrophy, residual signs of contusion of the brain, bilateral abscess-forming pyelonephritis, infected femoral shaft fracture.

Epicrisis: lack of cooperation due to severe craniocerebral injury; in-dwelling catheter caused urinary infection and pyelonephritis. Restlessness produced a large haematoma at the fracture site which, after rupture, probably became secondarily infected. Finally, death due to sepsis originating from the pyelonephritis.

Discussion: the movements in the fracture area could have been prevented by a stable osteosynthesis. Initially the severity of the cerebral injury and subsequently the fracture haematoma and the urinary infection contraindicated osteosynthesis. The extension treatment as such cannot be held responsible for the fatal issue, and it is questionable whether a different treatment could have altered the course. The prognosis seems to have been determined by the severity of the craniocerebral injury and the choice of treatment of urinary incontinence.

2. Patient nr. 110, a man aged 77, sustained a fall on the right hip which resulted in an oblique femoral shaft fracture. A wire extension was applied. The patient was suffering from diabetes

mellitus. Urinary incontinence and decubitus developed. After ten weeks the patient was transferred to a nursing-home. The fracture had failed to unite and showed an angular deformity (25° varus). Some five months after the accident the patient died in the nursing-home of cardiac failure, without having walked again.

Postmortem: not performed.

Epicrisis: urinary incontinence and decubitus developed during extension treatment. The patient died of cardiac failure before the fracture could heal.

Discussion: a stable osteosynthesis might possibly have prevented prolonged immobilization. Initially the diabetes mellitus was a relative, and subsequently the decubitus an absolute contraindication to osteosynthesis.

3. Patient nr. 089, a woman aged 90, was suffering from osteoarthritis of the right hip; in a dizzy spell she fell off a chair on the right hip, sustaining an oblique femoral shaft fracture. A wire extension was passed through the tibial tuberosity. Extensive decubitus of the sacral region gradually developed. The general condition deteriorated, and seven weeks after the accident the patient died from bronchopneumonia after aspiration.

Postmortem: aspiration pneumonia. Generalized arteriosclerosis and myocardial hypertrophy.
Epicrisis: severe decubitus during conservative treatment, followed by death from aspiration pneumonia.

Discussion: decubitus and aspiration might possibly have been avoided if a stable osteosynthesis had made it possible to discontinue immobilization at an early stage.

Deceased patients treated by Küntscher nail osteosynthesis:

1. Patient nr. 002, a woman aged 67, was hit by a car while walking, and sustained contusion of the brain, a closed transverse femoral shaft fracture and a contralateral tibial plateau fracture. She was comatose when admitted. A supracondylar wire extension was applied. Fat embolism with petechiae occurred two days later. Tracheotomy was performed. Open Küntscher nail osteosynthesis without reaming of the medullary cavity was carried out 25 days later. The osteosynthesis was not exercise-stable, and a plaster bandage was applied. Pyrexia occurred a few days after the operation; urinary infection and decubitus at the elbows developed. The osteosynthesis wound began to suppurate four weeks after the operation; Staphylococcus aureus and Clostridium perfringens were isolated from the discharge. The general condition gradually deteriorated; the decubitus exacerbated, and anaemia developed. The patient died six months after the accident.

Postmortem: foci of bronchopneumonia in the lungs; thrombosis in both femoral veins. Incipient decubitus ulcer on the anterior side of the oesophagus. Infected femoral shaft fracture.

Epicrisis: unstable osteosynthesis in a comatose patient with incipient decubitus and tracheotomy resulted in an infection. A few months later the patient died of bronchopneumonia and thrombosis.

Discussion: from the start, the prognosis was poor due to the severe brain damage. The attempt to exert a favourable influence on the prognosis by osteosynthesis, failed. The osteosynthesis was not stable, and an infection occurred. This may have caused further deterioration of the general condition. In this patient the osteosynthesis would seem to have had an adverse effect.

2. Patient nr. 141, a man aged 90, was suffering from hypertension, atrial fibrillation, chronic bronchitis and osteoarthritis of both hip-joints when he sustained a spiral femoral shaft fracture in a fall at home. A tibial tuberosity wire extension was applied, and the patient was digitalized. He became confused and decubitus developed. Open Küntscher nail osteosynthesis without reaming of the medullary cavity was carried out 12 days after the accident, with supplementary fixation by means of three screws. The osteosynthesis was not exercise-stable. The patient made an initially good recovery from the operation, but sudden death occurred on the third postoperative day, probably due to myocardial infarction.

Postmortem: not performed.

Epicrisis: sudden death after Küntscher nail

osteosynthesis of aged patient with pre-existent cardiac and pulmonary disease.

Discussion: the effect of treatment cannot be assessed due to the early death. It is not unlikely that death was related to the operation in this case.

3. Patient nr. 149, a man aged 61, was in a car collision and sustained contusion of the brain, an open femoral shaft fracture with butterfly, unstable thorax, rupture of the axillary artery and vein, and a lesion of the brachial plexus. The patient successively was submitted to: shock control, operative restoration of the continuity of axillary artery and vein, open Küntscher nail osteosynthesis without reaming of the medullary cavity, and tracheotomy. Controlled ventilation was required after the operation. The patient died with symptoms of decerebration six days after the accident.

Postmortem: severe cerebral oedema with renal shock. The cause of the cerebral oedema should probably be sought in the prolonged shock which the patient sustained.

Epicrisis: patient with multiple injuries died from decerebration a few days after the accident.

Discussion: it is unlikely that in this case a relationship existed between the osteosynthesis and the death.

4. Patient nr. 192/193, a woman aged 72, was hit by a car while walking. Injuries sustained: an contusion of the brain, pelvic fracture, scapular fracture, multiple costal fractures with unstable thorax, open fracture of the right and closed fracture of the left lower leg, and bilateral femoral shaft fracture (open on the right). After shock control and wound toilet, a tibial tuberosity and a calcaneus wire extension were applied to both legs. Controlled ventilation after tracheotomy. Bilateral open Küntscher nail osteosynthesis with reaming of the medullary cavity ten days after the accident. Both osteosyntheses were exercise-stable. The initial postoperative course was uneventful, but one month after osteosynthesis the patient died from severe bronchopneumonia.

Postmortem: bilateral bronchopneumonia, generalized arteriosclerosis.

Epicrisis: multiple injuries with ultimate death due to bronchopneumonia.

Discussion: the death was unrelated to the osteosynthesis, which has probably had a favourable effect on the nursability of this patient.

5. Patient nr. 078, a woman aged 85, fell at home and sustained a closed transverse femoral shaft fracture. Open Küntscher nail osteosynthesis without reaming of the medullary cavity was carried out four days after the accident. The osteosynthesis was not exercise-stable. In good condition, the patient was transferred to a nursing-home 12 days after the accident. In the nursing-home she died from uncertain causes almost three months after the accident. She was believed to have entered shock during a state of confusion.

Postmortem: not performed.

Epicrisis: death from uncertain causes of an aged woman, almost three months after sustaining a femoral shaft fracture.

Discussion: uncomplicated Küntscher nail osteosynthesis, the effect of which cannot be assessed. Death seemed to be unrelated to the treatment of the femoral shaft fracture.

6. Patient nr. 199, a woman aged 86, fell at home and sustained a spiral femoral shaft fracture. The patient was mentally disturbed and suffered from osteoarthritis of both hip-joints and heart disease. Open Küntscher nail osteosynthesis with reaming of the medullary cavity and cerclage was performed nine days after the accident. The osteosynthesis was not exercise-stable. After the operation she developed thrombosis and decubitus. Six weeks after the accident she was transferred in moderate condition to a nursing-home, where she died two months after the accident. The cause of death remained obscure.

Postmortem: not performed.

Epicrisis: aged, mentally disturbed patient with heart disease developed thrombosis following Küntscher nail osteosynthesis and died a few weeks later from unknown cause.

Discussion: the osteosynthesis failed to prevent decubitus because no exercise stability was

achieved. Thrombosis developed. The osteosynthesis probably had an untoward effect.

Deceased patients treated by A.O.-plate osteosynthesis:

1. Patient nr. 297, a man aged 56, was in a traffic accident on which no details are available. Shock, contusion of the brain, costal fractures and a comminuted femoral shaft fracture were diagnosed. Therapy consisted of: shock control, tibial tuberosity wire extension, tracheotomy, controlled ventilation and gastrostomy. An exercise-stable A.O.-plate osteosynthesis was effected seven days after the accident. To prevent thrombosis, heparin was given intravenously although there was a hetero-anamnestic report of a duodenal ulcer. Three days after the operation the patient suddenly died from massive haemorrhage from the ulcer.

Postmortem: haemorrhage from a duodenal ulcer.

Epicrisis: partly because of anticoagulant medication, this patient with severe craniocerebral injury died due to haemorrhage from a hetero-anamnestically reported duodenal ulcer.

Discussion: there seems to be no relationship between osteosynthesis and death. The nursability of this patient was enhanced by the exercise-stable osteosynthesis.

2. Patient nr. 305, a man aged 44, was hit by a car while walking and sustained contusion of the brain, bilateral costal fractures with unstable thorax, closed transverse femoral shaft fracture and an ankle fracture. On the day of the accident an exercise-stable A.O.-plate osteosynthesis was effected and, with a view to controlled ventilation, a tracheotomy was performed. On the day after the operation the patient died with symptoms of decerebration.

Postmortem: no information available.

Epicrisis: patient with multiple injuries died from decerebration.

Discussion: osteosynthesis and death were unrelated. Good nursing conditions were created by an exercise-stable osteosynthesis.

3. Patient nr. 325, a woman aged 83 with cardiac failure, a history of pulmonary tuberculosis, suffering from chronic obstructive lung disease and osteoarthritis of the right hip-joint, fell from her bed at home and sustained a spiral fracture of the right femoral shaft. A tibial tuberosity wire extension was applied. A.O.-plate osteosynthesis was effected four weeks after the accident. The osteosynthesis was entirely exercise-stable. Probably as a result of overdosage of anticoagulants, wound haematoma occurred. A gradually developing jaundice remained unexplained. Superficial wound infection and decubitus developed. The patient suddenly died three weeks after the operation.

Postmortem: not performed.

Epicrisis: osteosynthesis in an aged patient with several pre-existent diseases. Complications: postoperative haemorrhage and superficial wound infection; gradual jaundice preceded death, which was sudden and remained unexplained.

Discussion: in spite of an increased operative risk, osteosynthesis was carried out, whereupon several complications occurred. In view of the complications, some unfavourable effect should perhaps be assigned to the operation. No proper evaluation is possible because no postmortem was performed.

4. Patient nr. 296, a woman aged 90, fell from a stepladder and sustained a fracture of the maxilla and a closed comminuted fracture of the distal part of the femoral shaft. She had had a cerebral haemorrhage six weeks before the accident. Osteosynthesis by means of an A.O.-angle plate was carried out four days after the accident, with supplementary fixation by means of cerclage. The osteosynthesis was exercise-stable. Hemiplegia occurred five days after the operation. Decubitus gradually developed, and three weeks after the accident the patient died with symptoms of aspiration pneumonia.

Postmortem: bronchopneumonia, thrombosis in vena cava, embolism in the left pulmonary artery and chronic interstitial pyelonephritis.

Epicrisis: a few weeks after a cerebrovascular accident this aged patient fell and sustained a femoral shaft fracture treated by an exercise-stable osteosynthesis. After another cerebrovascular accident the patient aspirated and died

from bronchopneumonia. Pulmonary embolism was also found at postmortem examination.
Discussion: the patient died too soon after osteosynthesis to benefit from it. The exercise stability had created favourable conditions for ambulation and recovery.

5. Patient nr. 299, a woman aged 73 with hypertension, insufficiency of the basilar artery, diabetes mellitus and an alloplasty of the left hip-joint for medial femoral neck fracture (six years earlier) fell in a dizzy spell and sustained a spiral fracture of the left femoral shaft, immediately distal to the stem of the prosthesis. A.O.-plate osteosynthesis was carried out three days after the accident. The osteosynthesis was exercise-stable. The postoperative course was uneventful and patient was transferred to a nursing-home 16 days after the accident. Out-patient follow-up disclosed good restoration of function, although bony union was delayed. The patient died in the nursing-home five months after the accident. The cause of death remained obscure.

Postmortem: not performed.

Epicrisis: an aged woman with many pre-existent diseases died five months after A.O.-plate osteosynthesis for spiral femoral shaft fracture.

Discussion: death seems to be unrelated to treatment in this case. The operation probably had a beneficial effect because the osteosynthesis was exercise-stable.

A deceased patient treated by one of the other techniques of osteosynthesis:

1. Patient nr. 189, a man aged 81, was hit by a car while riding his bicycle and sustained a sternal fracture and a closed spiral fracture of the distal portion of the femoral shaft. After initial tibial tuberosity wire extension, open osteosynthesis was carried out 17 days after the accident by means of two interlocking Küntscher nails, inserted from the condyles. The osteosynthesis was not exercise-stable, and ten days later one of the nails had to be hammered in further because of distal migration. The patient's pre-existent dementia exacerbated in hospital, and decubitus developed. He was transferred to a nursing-home 51 days after the accident, and his general condition deteriorated further. After increasing dementia and extending decubitus the patient died, nearly three months after the accident.

Postmortem: not performed.

Epicrisis: aged demented patient died showing decubitus despite an attempt to shorten the period of immobilization by osteosynthesis. The cause of death remained obscure.

Discussion: the osteosynthesis was insufficient because it was not exercise-stable. The operation and re-operation must have had an untoward rather than a favourable effect.

Among the 35 patients who died between the time of discharge from the hospital and the summons for a follow-up, there are two whose deaths were related to the femoral shaft fracture or its treatment (table 72, Chapter IX). These two patients will be discussed here.

1. Patient nr. 127, a man aged 73 with myocardial hypertrophy, sustained a femoral shaft fracture due to the kickback of a lever against his thigh. The fracture was oblique, with a triangular fragment. Open Küntscher nail osteosynthesis without reaming of the medullary cavity was carried out the day after the accident. The osteosynthesis was not exercise-stable. Urinary retention called for insertion of an in-dwelling catheter, whereupon urinary infection developed. The patient developed pyelonephritis. Bilateral vasectomy was performed to prevent epididymitis. The patient was discharged with an indwelling catheter. This catheter was not removed until several months later, and meanwhile the patient had been examined in the Department of Internal Medicine in view of a high ESR (its cause was not established). Radiological follow-up on the femoral shaft fracture disclosed peculiar features. There was much callus with a marked periosteal reaction. These features were unfortunately not interpreted as those of osteitis. Six months after the accident benign hypertrophy of the prostate was treated by endoresection. A urinary infection again occurred and the accent of treatment thereafter shifted to the urological condition, at the expense of the femoral shaft fracture which had meanwhile attained bony union. Ten months after the accident the patient was admitted as an emergency with high fever, haematuria and pyuria. He died one week later.

Postmortem: bilateral pyelonephritis and pyelonephrosis. Unfortunately, examination of the femoral shaft fracture was omitted.

Epicrisis: in an aged patient, urinary retention after Küntscher nail osteosynthesis was treated by means of an in-dwelling catheter; recurrent urinary infection then developed. A peculiar radiological situation was found in the course of fracture union. The patient died from bilateral pyelonephritis ten months after the accident. The femoral shaft fracture was not examined at the postmortem.

Discussion: although neither histological nor bacteriological evidence of fracture infection was obtained, this probably did occur following Küntscher nail osteosynthesis. The radiological features are exceedingly suspect, and the repeatedly established increased ESR is also consistent with osteitis. Although the direct cause of death should probably be sought in faulty management of the urinary retention, yet fracture infection and prolonged immobilization must have played a role in this respect.

2. Patient nr. 311, a woman aged 84, stumbled and fell at home and sustained a transverse femoral shaft fracture with butterfly. Stable A.O.-plate osteosynthesis was effected the day after the accident. Symptoms of wound infection were observed three weeks after the operation, and Staphylococcus aureus was isolated from the discharge; osteitis gradually became manifest. Drainage was effected, and antibiotic medication given. The patient was discharged three months after the accident, but readmitted three months later because of continuing suppuration of the wound. The osteosynthesis material and a sequestrum were removed, and a fixateur externe was applied. Repeated bone grafts with autogenous cancellous bone were carried out during the following months. A urinary infection recurred several times, and the general condition deteriorated. Eleven months after the accident the patient was transferred to a nursing-home, which she left one month later against medical advice. Two days later she died at home. The family doctor considered pyelonephritis as the probable direct cause of death.

Postmortem: not performed.

Epicrisis: a femoral shaft fracture in an 84-year-old woman was treated by A.O.-plate osteosynthesis, whereupon infection occurred. The infection persisted despite several operations. The general condition deteriorated due to the prolonged immobilization. The patient finally died at home (probably from pyelonephritis) a year after the accident.

Discussion: the plate osteosynthesis had an adverse effect in this case. Instead of being ambulated early, the patient had to undergo several operations and was confined to bed for many months. Urinary infections and deterioration of the general condition finally led to death one year after the accident.

In considering the case histories of the patients who died in the course of conservative treatment, one may be inclined to relate the deaths to the prolonged immobilization in these cases. 'If only an operation had been performed, then the patient could have been ambulated early'. But consideration of the case histories of deceased patients who did undergo an operation shows that, in a number of cases, this operation had no beneficial effect. In cases in which an infection developed, the osteosynthesis in fact contributed to the death.

In all cases the purpose of the osteosynthesis was to create a possibility to ambulate the patient. But this possibility presents itself only if the osteosynthesis is exercise-stable.

VI.4. SUMMARY

This chapter presents a survey of the deceased patients and of the factors which contributed to the fatal issue.

The hospital mortality in this series is 8.8%, while the figures given for comparable series vary about the 10%.

The relevant data on the deceased patients are summarized in a table.

All deceased patients aged under 70 (except one) had sustained a severe craniocerebral injury. Patients in age group 70 and over as a rule died from complications, among which urinary infec-

tion, decubitus and bronchopneumonia were the principal causes of death. Occasional patients died as a result of exacerbation of pre-existent diseases.

In this series, one out of three patients who were 70 or older at the time of the accident, died within six months of the accident. There was no operative mortality (on the operating table or from postoperative shock).

The problems posed by prolonged immobilization, specifically decubitus and urinary infection, could not always be prevented by osteosynthesis. Not infrequently the following train of events was observed: the fear that a given aged patient might not tolerate the prolonged immobilization of conservative treatment led to a decision in favour of open reduction and fixation. At operation, however, the desired stability could not be achieved, and supplementary external fixation by means of a plaster bandage or balanced suspension traction had to be resorted to.

In these cases, however, the patient's situation was not improved because immobilization had to continue and in addition there was the traumatic impact of the operation and the risk of complications, e.g. infection. In this series, such an infection played an important role in the events leading to the fatal issue in three, and possibly in four, of the case histories presented.

It has been stated in the introduction to this chapter that the number of deceased patients is too small and the number of variables too large for meaningful statistical analysis. It is therefore merely an impression rather than a statistically verified finding that it is advisable in the treatment of aged patients not to decide in favour of osteosynthesis until it can be assumed that exercise stability will be achieved at this operation.

VI.5. REFERENCES

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Chapter VII
Duration of fracture union

VII.1. INTRODUCTION

Fracture union is a subject which attracks considerable interest. An exhaustive study of the literature (Brons 1970) has recently been published in Dutch. Controversial views continue to be presented. A detailed discussion of these controversies is not within the scope of this study.

This study confines itself to an analysis of the fracture union data on the series under discussion.

Some aspects of fracture union in compact bone tissue will be discussed to be used as reference for the findings obtained in this series.

VII.2. SOME ASPECTS AND DEFINITIONS OF FRACTURE UNION

In fracture union, several stages can be distinguished which can occur simultaneously or consecutively. In some cases (e.g. when stable osteosynthesis is achieved), certain stages are omitted.

During conservative treatment of fractures of the long bones, callus is formed which ensures the fixation of fracture fragments in relation to each other. Periosteal callus formation predominates in fractures involving compact bone tissue, while endosteal callus formation is predominant in fractures involving cancellous bone tissue (Urist and Johnson 1943; Charnley 1968).

Considerable research has been devoted to the origin of osteogenetic tissue. There are two opposing theories in this respect (Brons 1970): Lexer's classical osteoblast theory (1929), and the theory of induction. The classical osteoblast theory starts from the assumption that osteogenesis can only arise from specific osteogenetic tissue. The induction theory (advocates: Krompecher 1937; Weinman and Sicher 1955; Koekenberg 1963; Küntscher 1970) holds that young, non-specific stromal cells differentiate to osteogenetic cells in response to certain stimuli. Küntscher (1970) maintains that this stimulus is a chemical one and originates from dead bone cells. The 'callus cap' sometimes observed on that part of the Küntscher nail that protrudes from the trochanter, is used by Küntscher as an argument in evidence of heterotopic callus formation. The protruding nail causes tissue damage in movement. Through the hollow centre of the nail, fluid from the fracture site enters this damaged tissue. This fluid contains the chemical stimulus which induces callus formation in the damaged tissue. If the stimulus is small, then no callus cap is formed but a mucous bursa develops. There is believed to be a correlation between the local amount of callus at the fracture site and the size of the callus cap.

Koekenberg (1963) pointed out the importance of vascularization in fracture healing. Good vascularization ensures differentiation to osteoblasts, whereas differentiation to chondroblasts occurs when the vascularization is poor. He demonstrated in animal experiments that the endothelial cell of the vascular wall is able to differentiate to an osteoblast.

Geiser (1959) and Pritchard (1964) found that the size of the periosteal callus is directly proportional to the amount of mobility at the fracture site.

It seems, therefore, that biological (vascularization) as well as mechanical (immobilization) factors play a role in fracture union.

The union of anatomically reduced and stably fixed fractures differs from that in conservative treatment. Callus formation does not occur. Danis (1949) was among the first to observe this; he used the term 'soudure autogène' (autogenic soldering). Allgöwer (1969) suggested that, analogous to wound healing, distinction should be made between primary bony union and secondary bony union (via callus formation).

Basset (1962) and Wagner (1963) studied primary union in animal experiments. They demonstrated that, in stably fixed osteotomies, osteogenesis originates from the cut Haversian canals. The osteogenetic unit consists of:

1. vascular sprout;
2. perivascular osteoblasts;
3. 'bore head' of osteoclasts.

The A.O.-group in particular has done considerable research into primary bony union in fractures of the long bones in stable fixation (Allgöwer, Müller, Schenk and Willenegger 1963; Schenk and Willenegger 1964; Segmüller 1966; Allgöwer 1969; Hutzschenreuter, Perren, Steinemann, Geret and Klebl 1969). This primary union is believed to take a somewhat slower course than union via callus formation (Müller 1964). The high degree of stability required was achieved by compression osteosynthesis – a procedure in which the fracture fragments are fixed together under compression. Technical details can be found in the A.O. 'Manual' (Müller, Allgöwer and Willenegger 1965).

Holden (1972) believes that elimination of the nutrient artery in a fracture changes the circulation through the cortex from centrifugal to centripetal. This centripetal circulation originates from and is dependent on adjacent soft tissues. He demonstrated the plausibility of his hypothesis in animal experiments. Particularly in comminuted fractures, some fragments of which can be regarded as autogenous grafts, (re)vascularization from the soft tissues is of great importance. Holden concluded from his findings that in comminuted fractures an operation, if contemplated, is best postponed for a few weeks to give the circulation in the soft tissues and in the bone time to restore itself.

Küntscher (1970) as well as Charnley (1968) regarded the patient's age as a factor of importance in the duration of fracture union. Charnley assumed that union takes a slower course in young than in older patients. In young patients the compact bone contains a large amount of mineral material to meet the demands of firmness. Consequently there is little room for Haversian canals. In the osteoporotic bone tissue of aged patients the proportion between mineral material and Haversian canals is reversed. In young patients with a fracture, 'dilatation' of the Haversian canals must occur before the bone ends are sufficiently vascularized. Aged patients do not need this interval.

Küntscher, however, maintained that union in aged patients is slower because their ability to respond to the chemical stimulus should be less.

Both Charnley and Küntscher held that slow union is as a rule caused by local, not by general factors. One of their arguments was that, in double fractures, one fracture often units quickly and the other slowly. Both investigators also pointed out the influence of an infection on the duration of union. The periosteum is lifted off the bone over a considerable distance by pus; the avascular area is thus enlarged so that union is substantially delayed.

Studies have been made of a possible relationship between soft-tissue injury involved in a fracture, and the duration of fracture union. Attempts have been made to express the degree of soft-tissue injury with reference to the openness or closedness of a fracture.

Dencker (1963) went so far as to discuss his entire material in two separate groups: open and closed fractures. However, it is unlikely that openness or closedness alone should be a good parameter of soft-tissue injury. Charnley (1968) possibly found the best parameter, but it applies only to conservative fracture treatment. He mentioned the occurrence of distraction as one of the principal symptoms of severe soft-tissue injury, because distraction can only occur if the septa between the muscles are ruptured. And it is believed to be precisely along these septa that the callus bridges the fracture.

It is quite conceivable that the influence of accompanying soft-tissue injury on the duration of union is not the same for all fractures of long bones. One could imagine that the effect of a soft-tissue injury is more pronounced in fractures of the lower leg, with only a small amount of surrounding soft tissues, than in fractures of the femoral shaft, which is surrounded by an extensive sheath of soft tissues.

The initial dislocation measured from the acci-

dent radiograph is disregarded in this study because it is not a representative yardstick of the true dislocation.

A reliable conclusion on the effect of accompanying soft-tissue damage on the duration of fracture union therefore seems impossible because 'soft-tissue injury' as such is not quantifiable!

Brons (1970) concluded from his study of the literature that the causes of disturbed fracture union can be traced back to inadequate revascularization of the fracture area.

It has been maintained that the time of operation is of importance in operative fracture treatment. Charnley and Guindy (1961) and James (1964) found that, in femoral shaft fractures treated by Küntscher nail osteosynthesis, there were fewer instances of non-union after operations performed in the second or third week than after operations in the first week after the accident. Charnley and Guindy suggested two possible explanations for their findings:

* early intervention increases the volume of ischaemic cortical bone;
* later intervention applies a second osteogenetic stimulus to fractures inclined towards delayed union.

Lam (1964) made a similar study of a series of femoral shaft fractures treated by various methods. He, too, found more cases of non-union after operations performed in the first week after the accident than after later operations.

The experiments of Holden (1972) pointed in the same direction, but Rokkanen et al. (1969) and Blichert-Toft and Hammer (1970) found what seemed rather the opposite effect in their series! However, the criteria of union applied in the various studies differed. Moreover, the question arises whether the distinction made between 'early' and 'delayed' is a proper one. Finally, the criterion of the percentage of disturbances in union seems less exact than a comparison based on the overall duration of union in the various groups.

After stable internal fixation there is no possibility to follow the progress of union by testing the stability of the fracture. Other criteria have to be found. Table 49 lists a number of criteria formulated in the literature.

Several authors make use of criteria based on clinical observations. A number of objections can be made to these criteria. For example, the time at which a limb is exposed to weightbearing is dependent, not only on the degree of union of the femoral shaft fracture but also on the degree of healing of associated injuries, if any. The same applies to the time of resuming work. Another

Table 49. Survey of criteria of union formulated in the literature.

Author, year of publication		Source of data	Formulation of criterion of union
Charnley, J. & Guindy, A.	1961	radiological	the presence of continuous bridging of bone at some part of the fracture, though not necessarily on all sides, combined with the absence of sclerosis
Smith, J. E. M.	1964	radiological and clinical	when the fracture was seen to be bridged by bone, and full weight bearing was possible without protection of the limb
Lam, S. J.	1964	radiological and clinical	when callus was visible in the radiographs and when full weight could be borne on the affected limb
Rokkanen, P. et al.	1969	clinical	the ability to walk without a stick and the return to work (for conservatively treated fractures: the discontinuance of immobilization)
Blichert-Toft, M. & Hammer, A.	1970	radiological and clinical	when the patient was able to stand on the leg without pain at the site of the fracture which must have become consolidated, showing radiological union

objection is the fact that these clinical observations are often incompletely recorded and therefore give unreliable information.

Especially in retrospective studies, therefore, it is better to use the information which radiographs offer. Radiographs are unequivocal documents which can be compared. Problems might arise in the interpretation in primary bony union. But in actual practice this problem does not arise with femoral shaft fractures, in which primary union is rarely observed.

In view of the above considerations the criterion formulated by Charnley and Guindy has been adopted in this study. It reads: 'The criterion for osseous union is the presence of continuous bridging of bone at some part of the fracture, though not necessarily on all sides, combined with the absence of sclerosis'.

Delayed union and pseudarthrosis are concepts frequently used in the literature without being clearly defined. In fact it is almost impossible to define them! Delayed union is an arbitrary concept, which implies that a fracture has not yet united although normally it could have been expected to.

In imitation of Dencker (1963) the designation delayed union is used in this study when no full union has been attained after eight months. This eight-month limit is based on Dencker's observation that a femoral shaft fracture which needs more than eight months to attain full union often shows a poor functional end-result. This, therefore, is a criterion based on practice. In addition to it, Dencker applied a second criterion: he spoke of delayed union if the attending surgeon had to perform an operation within eight months of the accident to speed up union.

In the present series, intervention within eight months was very rare; and in that case fracture union was always achieved within eight months. There is therefore no reason to apply Dencker's second criterion in the present series.

Pseudarthrosis or non-union refers to failure of the fracture to unite. It is impossible to differentiate exactly between delayed union and non-union. When examination of a number of radiographs obtained at long intervals reveals no progress of fracture union at all, and when sclerosis of the bone ends is in evidence, the term non-union is applied in this study.

In Anglo-American literature the term 'mal-union' is used with reference to a fracture which has united in an incorrect position. Since this term gives no information on the process of fracture union as such, it is not used in this chapter.

VII.3. MATERIAL AND METHODS

Radiographs of all fractures were studied in an effort to establish the time (in months) required by the fracture to attain full union. The evaluation was always made by the same person (the author). The radiographs were as a rule obtained at one-month intervals. This is a high frequency of radiographic follow-up, perhaps even too high, particularly in operative treatment. But, in retrospect, grateful use can be made of this information in this study. When the interval between two follow-up radiographs exceeded one month, and when union was achieved during this interval, the month of union was estimated. But this was not considered justifiable when the interval between the radiograph before and that after union exceeded four months. For this reason, twelve fractures were excluded from the calculations. No union radiograph could be obtained for four patients, who failed to report for follow-up.

For the patients given further treatment elsewhere, it was as a rule possible to obtain adequate information from radiographs made available on request. Seven patients were an exception to this rule.

Since the calculations concerning fracture union will be related to the four different methods of treatment, the fractures in the 'unclassifiable' group were likewise eliminated (so far as they had not already been eliminated for other reasons).

In four patients who were submitted to amputation, of course, no observations of this kind were made; and the same applies to patients who died within six months of the accident. Table 50 lists the number of fractures eliminated for the various reasons mentioned.

It follows from table 50 that no observations on fracture union are available for 68 of the total of 329 femoral shaft fractures. These 68 fractures include a number which did not unite as desired.

Table 50. Reasons for elimination of fractures from union calculations.

reasons for elimination	number of fractures
deceased in hospital or nursing-home	29
amputation	4
further treatment elsewhere with insufficient information	7
evasion of follow-ups	4
insufficient information	12
remainder from 'unclassifiable' group	12
total	68

This was the case with a few of the deceased patients and one of the four amputation patients. These patients will be considered in the discussion of complications in Chapter VIII.

Fracture union occurred in all patients who received aftercare elsewhere and on whom insufficient information is available. As pointed out, the duration of fracture union in these cases is unknown. The same applies to the patients who withdrew from follow-up and those whose radiological follow-ups were made at too long intervals.

The 'unclassifiable' group includes a few cases in which fracture union was unmistakably disturbed. These fractures will be discussed in the chapter on complications. The three patients in this group whose conservative treatment was discontinued in favour of an operation three to five months after the accident, cannot be recorded under the heading 'disturbed fracture union' because union occurred within eight months of the intervention (in spite of or owing to?). Although the duration of union in these cases is known, they yield no valid information for comparison of methods of treatment, and were eliminated for this reason.

Calculations concerning fracture union were ultimately based on 261 femoral shaft fractures. The distribution of fracture union over this material is shown in fig. 32.

Fig. 32 shows that 240 fractures attained full union within six months of the accident (84.3 %). The rate of full union within eight months was 93.4 %. Given the definition of 'disturbed union', it was found that 6.6 % of the fractures showed such a disturbance.

It has been pointed out in Chapter III that statistical testing was done with the aid of a rank order test: the Mann-Whitney U-test. This test compares the duration of union of two groups. In a number of cases there are differences in variables other than that which determines the group. The extent to which these differences influence the findings can only partly be determined. In this context it may be useful to point out that the calculations presented in the following do not warrant definite black-white conclusions. It is better to interpret the results as showing a trend in a certain direction, always bearing in mind that this applies to the material under discussion under all the circumstances involved.

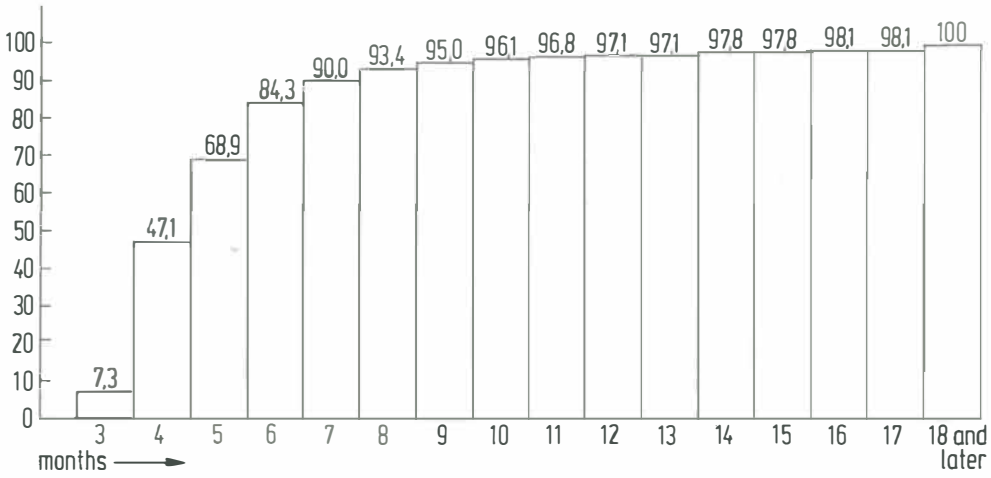

Figure 32. Graph showing cumulative percentages of fracture unions per month.

VII.4. DURATION OF UNION AND METHOD OF TREATMENT

The first comparison in this respect is between conservatively and operatively treated fractures. The comparability of the groups was examined in accordance with the criteria defined in Chapter V.

Significant differences proved to exist only in the distribution over:

* accident groups
* fracture groups
* shaft segments involved
* antibiotic medication
* prophylactic anticoagulant medication.

The data with the corresponding Chi-square test results are presented in tables 51 through 54. For the sake of brevity the data showing no significant differences in distribution are not listed.

Table 51. Distribution of conservatively and operatively treated fractures over accident groups.

	traffic	work	home
conservative	59 (66%)	11 (12%)	19 (21%)
operative	161 (79%)	20 (10%)	22 (11%)

$\chi_{(2)}^2 = 6.62$
significant ($p < 0.02$)

The difference lies mainly in the fact that the group 'operatively treated fractures' includes relatively more fractures due to traffic accidents.

Table 52. Distribution of conservatively and operatively treated fractures over fracture groups.

	bending	comminuted	torque
conservative	42 (47%)	32 (36%)	15 (17%)
operative	165 (81%)	25 (12%)	13 (6%)

$\chi_{(2)}^2 = 34.90$
significant ($p < 0.001$)

The differences in distribution over the fracture groups implies a difference also in shaft segment involved. Data on the latter are omitted for brevity's sake.

Antibiotic medication was given significantly more often to patients treated by operation than to conservatively treated patients.

Conservatively treated patients were significantly more often given prophylactic anticoagulant medication than patients treated by operation.

Table 53. Comparison between conservatively and operatively treated fractures as regards antibiotic medication.

	no antibiotics	antibiotics
conservative	40 (47%)	46 (53%)
operative	55 (27%)	152 (73%)

$\chi_{(1)}^2 = 10.13$
significant ($p < 0.001$)

Table 54. Comparison between conservatively and operatively treated fractures as regards prophylactic anticoagulant medication.

	no anticoagulants	anticoagulants
conservative	41 (48%)	44 (52%)
operative	128 (62%)	79 (38%)

$\chi_{(1)}^2 = 4.03$
significant ($p < 0.05$)

It has been pointed out in Chapter V that it is questionable whether antibiotics and anticoagulants exert an influence on fracture union. In other words: it is questionable whether the differences found are relevant.

The differences between fracture groups and between shaft segments involved are possibly relevant. These differences result from the fact that one fracture is better suited to internal fixation than the other.

The difference in fracture groups probably determines the difference in accident groups. The importance of the differences found and the extent of their influence cannot be established.

The data on the comparison between conservatively and operatively treated fractures in terms of duration of union are summarized in table 55. The table shows that the duration of union in conservative fracture treatment differs significantly from that in operative fracture treatment. However, in this calculation all observations on the operatively treated fractures have been summated. It is more interesting to consider the duration of union in relation to the four different types of treatment. The comparability of these types of treatment was discussed in Chapter V,

and differences were found with regard to accident group and fracture group. The calculations of the duration of union in the four different types of treatment led to the results listed in table 56. (see page 64)

Table 55. Comparison between conservatively and operatively treated fractures as regards duration of union.

month of union	conservative number	cum.%	operative number	cum.%
3rd	11	13.4%	8	4.4%
4th	36	57.4%	68	42.4%
5th	17	78.1%	40	64.7%
6th	12	92.7%	28	80.3%
7th	2	95.1%	13	87.5%
8th	0	95.1%	9	92.5%
9th	2	97.5%	1	93.0%
10th	1	98.7%	2	94.0%
11th	1	100.0%	1	94.5%
12th	0		1	95.0%
14th	0		2	96.0%
16th	0		1	96.5%
18th and later	0		5	100.0%
numbers	82		179	
mean ranks*	111.25		140.25	

test = 2.979, significant ($p < 0.01$)

* The 'mean ranks' concept requires some elucidation. In the test procedure the data of both groups are scored in rank order from low to high. The ranks of the elements of both groups are determined. A conclusion on the statistical difference is based on the predominance or non-predominance of high (or low) ranks in one of the groups. The mean ranks give an indication of this.

It can be deduced from table 56 that the conclusion which links operative treatment with a longer duration of union is valid only for the group 'Küntscher nail without' (reaming). The group 'Küntscher nail with' is not statistically different in duration of union from the conservatively treated group. The group 'AO-plate' shows a tendency towards longer duration of union than the conservatively treated group, but the difference is not significant.

In the group of operative types of treatment there is a significant difference between 'Küntscher nail without' and 'Küntscher nail with', in favour of the latter.

The favourable findings with regard to duration of union in the group 'Küntscher nail with' have two aspects which invite comment. To begin with, this group encompasses very few comminuted fractures indeed (table 44), and this may flatter the outcome. Secondly the suggestion has arisen that the favourable outcome may result from the fact that closed reduction was effected in some two-thirds of the fractures in this group, whereas open reduction was effected in virtually all cases in the group 'Küntscher nail without'.

So as to gain some insight into the effect of closed reduction, the group 'Küntscher nail with' was divided into a subgroup 'open reduction' and a subgroup 'closed reduction'. For completeness' sake the group 'Küntscher nail without' was also included in the calculations. The relevant figures are presented in table 57 (see page 64). Table 57 shows no difference in duration of union between the above-mentioned subgroups 'open reduction' and 'closed reduction' of the group 'Küntscher nail with'. But in both subgroups the duration of union is shorter than that in the group 'Küntscher nail without'.

The above findings would seem to warrant some tentative conclusions. Femoral shaft fractures treated by Küntscher nail osteosynthesis without reaming of the medullary cavity unite significantly more slowly than conservatively treated fractures. Fractures treated by Küntscher nailing with reaming do not significantly differ in duration of union from conservatively treated fractures. The favourable effect of reaming of the medullary cavity may probably be attributed to the higher degree of stability achieved by this technique. It seems to make no difference whether an open or a closed procedure is used for this technique. The duration of union of femoral shaft fractures treated by A.O.-plate osteosynthesis is intermediate between the durations with the two Küntscher nailing techniques and does not significantly differ from either of these techniques.

Table 56. Comparison between the four methods of treatment as regards duration of union.

Month of union	Conservative number	cum.%	K-nail without number	cum.%	K-nail with number	cum.%	AO-plate number	cum.%
3rd	11	13.4%	3	3.0%	3	6.6%	2	5.4%
4th	36	57.4%	28	31.9%	24	60.0%	16	48.6%
5th	17	78.1%	21	53.6%	12	86.7%	7	67.5%
6th	12	92.7%	24	78.4%	3	93.3%	1	70.2%
7th	2	95.1%	7	85.7%	2	97.8%	4	81.1%
8th	0	95.1%	7	93.0%	0	97.8%	2	86.5%
9th	2	97.5%	0	93.0%	0	97.8%	1	89.2%
10th	1	98.7%	1	94.0%	0	97.8%	1	91.9%
11th	1	100.0%	1	95.0%	0	97.8%	0	91.9%
12th	0		1	96.0%	0	97.8%	0	91.9%
14th	0		1	97.0%	0	97.8%	1	94.6%
16th	0		1	98.0%	0	97.8%	0	94.6%
18th and later	0		2	100.0%	1	100.0%	2	100.0%
numbers	82		97		45		37	

comparison between	mean ranks	test	difference is:
cons. and K-nail without	73.49 and 103.96	4.052	significant ($p < 0.0001$)
cons. and K-nail with	64.25 and 63.54	0.110	not significant
cons. and AO-plate	56.61 and 67.73	1.725	not significant
K-nail without and K-nail with	80.01 and 53.17	3.749	significant ($p < 0.001$)
K-nail without and AO-plate	69.64 and 61.88	1.063	not significant
K-nail with and AO-plate	37.88 and 45.91	1.628	not significant

Table 57. Comparison of Küntscher-nailed groups as regards duration of union.

Month of union	K-nail without number	cum.%	K-nail with, open number	cum.%	K-nail with, closed number	cum.%
3rd	3	3.0%	2	11.7%	1	3.6%
4th	28	31.9%	8	58.7%	16	60.7%
5th	21	53.6%	3	76.4%	9	92.8%
6th	24	78.4%	1	82.3%	2	100.0%
7th	7	85.7%	2	94.0%	0	
8th	7	93.0%	0	94.0%	0	
9th	0	93.0%	0	94.0%	0	
10th	1	94.0%	0	94.0%	0	
11th	1	95.0%	0	94.0%	0	
12th	1	96.0%	0	94.0%	0	
14th	1	97.0%	0	94.0%	0	
16th	1	98.0%	0	94.0%	0	
18th and later	2	100.0%	1	100.0%	0	
numbers	97		17		28	

comparison between	mean ranks	test	difference is:
K-nail without and K-nail with, open	59.99 and 43.26	1.977	significant ($p < 0.05$)
K-nail without and K-nail with, closed	69.01 and 42.18	3.574	significant ($p < 0.01$)
K-nail with, open, and K-nail with, closed	23.62 and 22.63	0.270	not significant

VII.5. DURATION OF UNION AND EARLY OR DELAYED INTERVENTION

It has been pointed out in section VII.2 that some investigators reported differences in the incidence of disturbed union between fractures treated by early and those treated by later (delayed) operation. The comparison was alleged to be in favour of the delayed interventions. Other investigators have refuted this.

Most of these studies compare union after operation in the first week following the accident with that after operation during subsequent weeks. The margin between these two groups is too narrow. After all, an operation on the sixth day after the accident is 'early', while one on the seventh day is 'delayed'. In order to ensure a sharper contrast, it seems better to differentiate between operation on the day of the accident or the next day, and operation performed in the second, third and fourth week. The criteria in the literature and those in the present study are listed in table 58.

Table 58. Criteria of 'early' and 'delayed' intervention.

authors		early	delayed
Charnley and Guindy	(1961)	0–6 days	7–28 days
Smith	(1964)	0–6 days	7–56 days
Lam	(1964)	0–6 days	7–42 days
Rokkanen et al.	(1969)	0–6 days	7–21 days
present study		0–1 day	7–28 days

In terms of the criteria formulated in Chapter V, the groups 'early' and 'delayed' differ only in two respects: accident type and method of treatment. Tables 59 and 60 list the figures on which the differences are based, with the corresponding Chi-square test.

Table 59. Distribution of accident groups over early and delayed intervention.

	traffic	work	home
early	42 (70%)	10 (17%)	8 (13%)
delayed	88 (85%)	6 (6%)	10 (10%)

$\chi_{(2)}^2 = 6.13$
significant ($p < 0.05$)

The difference with regard to accident type is small and probably not relevant.

Table 60. Distribution of methods of treatment over early and delayed intervention.

	K-nail without	K-nail with	AO-plate
early	45 (75%)	5 (8%)	10 (17%)
delayed	43 (43%)	35 (35%)	21 (21%)

$\chi_{(2)}^2 = 17.96$
significant ($p < 0.001$)

The distribution of methods of treatment over the groups 'early' and 'delayed' shows important differences. For example, the group 'Küntscher nail without' is strongly represented in the group 'early'. These differences probably do have relevance, and the exact influence can be established only by further subdivision of the material.

Of the 179 operatively treated fractures, 36 are eliminated because the operation was performed in the interval between 'early' and 'delayed'. Calculations with regard to early and delayed intervention are presented in table 61.

Table 61. Comparison between early and delayed intervention as regards duration of union.

Month of union	Early intervention number	cum.%	Delayed intervention number	cum.%
3rd	1	2%	7	7.6%
4th	11	24%	45	56.6%
5th	9	42%	19	77.2%
6th	11	64%	7	84.8%
7th	6	76%	6	91.4%
8th	4	84%	4	95.7%
9th	0	84%	1	96.7%
10th	1	86%	1	97.7%
11th	1	88%	0	97.7%
12th	0	88%	2	100.0%
14th	1	90%	0	
16th	1	92%	0	
18th and later	5	100%	0	
total number	51		92	
mean ranks	91.77		61.04	

test = 4.408, significant ($p < 0.00001$)

Table 61 shows a highly significant difference in duration of union between the groups 'early' and 'delayed', in favour of the group 'delayed'. In order to establish whether this is not caused by the large number of 'Küntscher nail without' cases in the group 'early', the groups are divided according to method of treatment in table 62. For completeness' sake the column 'conservatively treated fractures' was included in the calculations.

In Küntscher nail osteosynthesis there proves to be a significant difference between 'early' and 'delayed', in favour of the latter. The difference for A.O.-plate osteosynthesis is not significant, but the same trend is discernible.

This means that the longer duration of union indicated for 'early' in table 61 (entire material) is probably indeed due to the early intervention, not to the large number of 'Küntscher nail without' cases in this group.

Table 62. Comparison between conservatively and operatively treated fractures (the latter subdivided into 'early' and 'delayed') as regards duration of union.

Month of union	Conservative		K-nail without				K-nail with				AO-plate			
			early		delayed		early		delayed		early		delayed	
	nr.	cum.%	nr.	cum.%	nr.	cum.%	nr.	cum.%	nr.	cum.%	nr.	cum.%	nr.	cum.%
3rd	11	13.4%	0		3	8.1%	0		3	9.7%	1	11.1%	1	5.5%
4th	36	57.4%	9	24.3%	12	40.5%	0		20	74.2%	2	33.3%	11	66.6%
5th	17	78.1%	7	43.2%	9	64.8%	2	40%	6	93.6%	0	33.3%	3	83.2%
6th	12	92.7%	9	67.5%	5	78.3%	1	60%	1	96.8%	1	44.4%	0	83.2%
7th	2	95.1%	4	78.3%	3	86.4%	1	80%	1	100.0%	1	55.5%	2	94.3%
8th	0	95.1%	3	86.3%	4	97.2%	0	80%	0		1	66.6%	0	94.3%
9th	2	97.5%	0	86.3%	0	97.2%	0	80%	0		0	66.6%	0	94.3%
10th	1	98.7%	1	89.2%	0	97.2%	0	80%	0		0	66.6%	1	100.0%
11th	1	100.0%	1	92.1%	0	97.2%	0	80%	0		0	66.6%	0	
12th	0		0	92.1%	1	100.0%	0	80%	0		0	66.6%	0	
14th	0		0	92.1%	0		0	80%	0		1	77.7%	0	
16th	0		1	95.0%	0		0	80%	0		0	77.7%	0	
18th and later	0		2	100.0%	0		1	100%	0		2	100.0%	0	
total nr.	82		37		37		5		31		9		18	

comparison between	mean ranks	test	difference is:
K-nail without, early, and K-nail without, delayed	42.43 and 32.68	1.971	significant ($p < 0.05$)
K-nail with, early, and K-nail with, delayed	31.60 and 16.39	3.314	significant ($p < 0.001$)
AO-plate, early, and AO-plate, delayed	18.73 and 12.08	1.885	not significant

Table 63. Comparison between conservatively and operatively treated fractures (the latter subdivided into 'early' and 'delayed') as regards duration of union.

Comparison between:	mean ranks	test	difference is:
Cons. and K-nail without, early	51.31 and 79.26	4.239	signif. ($p < 0.0001$)
Cons. and K-nail with, early	42.35 and 71.00	2.576	signif. ($p < 0.02$)
Cons. and AO-plate, early	43.98 and 64.39	2.300	signif. ($p < 0.05$)
Cons. and K-nail without, delayed	56.07 and 68.70	1.928	not significant
Cons. and K-nail with, delayed	59.37 and 50.73	1.345	not significant
Cons. and AO-plate, delayed	50.65 and 49.81	0.119	not significant

Comparison of the duration of union in conservatively treated fractures with that in fractures treated by 'early' and 'delayed' intervention, respectively, yields yet another significant finding. Table 63 presents the calculations based on table 62.

Table 63 shows that the duration of union is significantly longer in all cases of group 'early' than in the group of conservatively treated fractures, whereas no significant differences are demonstrable between the groups 'delayed' and conservatively treated fractures.

The only possible explanation would seem to be that internal fixation constitutes an additional lesion, which aggravates the circulatory disturbance resulting from the accident. Operation after a few weeks also entails additional violence, but this is inflicted upon different tissue. At that time the bone is hyperaemic and in a state of great activity. Schenk and Willenegger (1964), using tetracycline labelling in dogs, found that the number of active osteons four weeks after an osteotomy was about 3% on the unaffected side (i.e. representative of the situation at rest), while that on the osteotomy side amounted to 30%.

VII.6. VARIOUS CALCULATIONS WITH REGARD TO THE DURATION OF UNION

The duration of union of closed fractures was compared with that of open fractures. In terms of the factors mentioned in Chapter V the two groups differ only in accident type and fracture type. This was already known: comminuted fractures are more frequently open, while torque fractures (accidents at home) are never open. The two groups show the same 'early' and 'delayed' distribution!

Table 64. Comparison between open and closed fractures as regards duration of union.

Month of union	closed fractures number	cum. %	open fractures number	cum. %
3rd	16	6.9%	3	8.0%
4th	94	47.6%	11	36.9%
5th	49	68.8%	10	63.1%
6th	38	85.2%	3	71.1%
7th	14	91.2%	2	76.3%
8th	9	95.0%	2	81.5%
9th	2	95.9%	1	84.2%
10th	2	96.8%	1	86.9%
11th	1	97.2%	0	86.9%
12th	0	97.2%	2	92.1%
14th	3	98.6%	0	92.1%
16th	0	98.6%	1	94.8%
18th and later	3	100.0%	2	100.0%
numbers	231		38	
mean ranks	132.29		151.50	

test = 1.466, not significant

The open fractures do show a higher mean rank, but the difference is not significant.

Since a correlation may be assumed to exist between the severity of soft-tissue injury and the duration of union, the above finding confirms the hypothesis advanced in section VII.2 that openness or closedness of a fracture is not a reliable criterion of the degree of soft-tissue damage.

The difference in duration of union between the different fracture types was also studied. In preceding chapters, substantial differences between the groups were demonstrated with regard to the distribution over sexes, age groups, accident types, open and closed fractures and method of treatment. So far as the fractures were given operative treatment, there were no differences between early and delayed intervention.

There is a significant difference in duration of union between torque fractures and comminuted fractures in favour of the former. The question is which value should be attached to this finding in view of the differences in composition between the groups. (table 65, see page 68).

The duration of union per age group was also compared. Again it was found that the groups show substantial differences in several of the factors considered. Four age groups were formed: 17–29, 30–49, 50–69 and 70 and over (table 66). The duration of union is significantly shorter in the group of young patients (17–29) than in the two middle-aged groups. The same trend is apparent in comparison with the aged patients but this difference is not significant. There are no significant differences between the other groups.

Table 65. Duration of union and fracture types.

Month of union	Bending fractures		Comminuted fractures		Torque fractures	
	number	cum. %	number	cum. %	number	cum. %
3rd	11	5.7%	5	9.0%	2	9.5%
4th	81	48.1%	15	36.2%	9	52.3%
5th	42	70.1%	9	52.5%	7	85.7%
6th	26	83.7%	12	74.3%	2	95.2%
7th	10	89.0%	5	83.3%	0	95.2%
8th	8	93.2%	3	88.8%	1	100.0%
9th	3	94.8%	1	90.7%	0	
10th	2	95.8%	1	92.6%	0	
11th	2	96.8%	0	92.6%	0	
12th	0	96.8%	1	94.5%	0	
14th	3	98.4%	0	94.5%	0	
16th	0	98.4%	1	96.4%	0	
18th and later	3	100.0%	2	100.0%	0	
numbers	191		55		21	

comparison between:	mean ranks	test	difference is:
bending and comminuted	119.37 and 137.85	1.762	not significant
bending and torque	107.92 and 93.55	1.070	not significant
comminuted and torque	41.61 and 30.36	2.036	signif. ($p < 0.05$)

Table 66. Duration of union in the four age groups.

Month of union	Group 17–29		Group 30–49		Group 50–69		Group 70 and over	
	number	cum. %	number	cum. %	number	cum. %	number	cum. %
3rd	9	8.3%	4	5.0%	4	6.0%	2	7.4%
4th	55	59.3%	24	39.3%	18	32.9%	9	40.7%
5th	19	76.9%	15	60.7%	18	59.8%	7	66.6%
6th	15	90.9%	13	79.2%	10	74.8%	4	81.6%
7th	5	95.5%	6	87.8%	5	82.2%	0	81.6%
8th	2	97.4%	4	93.5%	5	89.6%	0	81.6%
9th	0	97.4%	1	95.0%	1	91.1%	1	85.3%
10th	1	98.3%	0	95.0%	1	92.6%	1	89.0%
11th	0	98.3%	0	95.0%	1	94.1%	1	92.7%
12th	1	99.2%	0	95.0%	1	95.6%	0	92.7%
14th	1	100.0%	1	96.5%	0	95.6 %	1	96.4%
16th	0		0	96.5%	1	97.1%	0	96.4%
18th and later	0		2	100.0%	2	100.0%	1	100.0%
numbers	108		70		67		27	

Comparison between groups:	mean ranks	test	difference is:
17–29 and 30–49	81.72 and 101.51	2.637	significant ($p < 0.01$)
17–29 and 50–69	78.24 and 103.74	3.385	significant ($p < 0.001$)
17–29 and 70 and over	65.33 and 78.67	1.686	not significant
30–49 and 50–59	66.52 and 71.59	0.766	not significant
30–49 and 70 and over	49.19 and 48.50	0.112	not significant
50–69 and 70 and over	48.57 and 44.83	0.616	not significant

These findings support neither of the controversial views of Charnley (1968) and Küntscher (1970).

Finally an attempt was made to establish whether the stability achieved by osteosynthesis could possibly play a role in the duration of union. For this purpose three groups were formed on the basis of operation protocols and radiographs: no exercise stability, limited exercise stability, and full exercise stability.

'No exercise stability' means that neither angulation nor rotation are controlled by the osteosynthesis; external fixation (splinting or extension) is required.

'Limited exercise stability' means that angulation is as a rule controlled by the osteosynthesis, but not rotation.

'Full exercise stability' means that the osteosynthesis is sufficiently stable to permit unsupported exercise of the limb after wound healing. This degree of stability is as a rule achieved by A.O.-plate osteosynthesis and by Küntscher nail osteosynthesis with reaming of the medullary cavity, provided the fracture is localized in the isthmus.

The literature uses the term weight-bearing stability, meaning that the limb can be exposed to weight-bearing after wound healing. After A.O.-plate osteosynthesis there can be no question of weight-bearing stability unless two plates at an angle of 90° are used. However, this technique has been rejected for routine use (Richon et al. 1967). After Küntscher nail osteosynthesis with reaming of the medullary cavity, using a nail of large diameter, weight-bearing stability is sometimes achieved if the fracture is localized in the isthmus.

In the series under discussion, no efforts to ensure weightbearing stability were made in principle, unless an incidental chance presented itself; even then, a wide margin of safety was taken.

The 'no exercise stability' group probably includes a large number of Küntscher nail osteosyntheses without reaming. Also, the same degree of stability will as a rule be less readily achieved in comminuted than in bending fractures.

The results of the following calculations should therefore be interpreted with some prudence with regard to the comparability of the groups. The group 'conservatively treated fractures' was included in the comparison for the sake of completeness.

Table 67. Comparison between the three osteosynthesis groups of different stability and the conservatively treated group as regards duration of union.

Month of union	Conservative		No stability		Limited stability		Full stability	
	number	cum. %	number	cum. %	number	cum. %	number	cum. %
3rd	11	13.4%	2	2.0%	3	10.3%	3	5.7%
4th	36	57.4%	32	34.6%	10	44.7%	26	55.7%
5th	17	78.1%	22	57.0%	8	72.2%	10	74.9%
6th	12	92.7%	20	77.4%	5	89.4%	3	80.6%
7th	2	95.1%	8	85.5%	2	96.4%	3	86.3%
8th	0	95.1%	7	92.6%	0	96.4%	2	90.3%
9th	2	97.5%	0	92.6%	0	96.4%	1	92.3%
10th	1	98.7%	0	92.6%	1	100.0%	1	94.3%
11th	1	100.0%	1	93.6%	0		0	94.3%
12th	0		1	94.6%	0		0	94.3%
14th	0		1	95.6%	0		1	96.3%
16th	0		1	96.6%	0		0	96.3%
18th and later	0		3	100.0%	0		2	100.0%
numbers	82		98		29		52	

Comparison between:	mean ranks	test	difference is:
conserv. and no stability	74.92 and 103.54	3.806	significant ($p < 0.001$)
conserv. and limited stability	54.22 and 61.03	1.026	not significant
conserv. and full stability	65.11 and 71.27	0.948	not significant
no stabil. and limited stability	67.03 and 53.76	1.757	not significant
no stabil. and full stability	81.07 and 65.01	2.235	significant ($p < 0.05$)
limited stabil. and full stability	41.71 and 40.61	0.213	not significant

It is shown that no exercise stability is associated with a longer duration of union than that in the full exercise stability group and that in the conservatively treated group. The same trend is apparent in comparison with the limited exercise stability group, but this difference is not significant. No significant differences exist between the groups conservative, limited exercise stability, and full exercise stability.

VII.7. SUMMARY AND CONCLUSIONS

A brief survey of some clinical aspects of the union of fractures of the long bones was presented in section VII.2. Data on duration of union are available on 261 femoral shaft fractures. Several groups were formed and compared with regard to duration of union. In all cases efforts were made to establish the extent to which the groups show certain differences in composition as regards the distribution over:

* sexes
* age groups
* pre-existent diseases
* accident groups
* presence of general associated injuries
* presence of craniocerebral injury
* presence of local associated injuries
* presence of homolateral lower leg fracture
* open or closed fracture
* fracture types
* shaft segment involved
* antibiotic medication
* prophylactic anticoagulant medication.

Some important findings emerge from the calculations, but these should be interpreted while accounting for all differences in conditions in the material studied.

The following points can be made:

1. Union is slower after Küntscher nail osteosynthesis *without* reaming of the medullary cavity than in conservative treatment. Küntscher nail osteosynthesis *with* reaming and conservative treatment are associated with the same duration of union. A possible explanation of this difference is that after 'Küntscher nail without' the traumatic effect of the operation is not compensated by stability. Dencker found that 'Küntscher nail without' caused significantly more disturbances of union than conservative treatment. The present study considers not the rate of union disturbance but the overall duration of union. While the two series show a shade of difference in the test criterion used, they lead to similar conclusions.

2. Küntscher nail osteosynthesis with reaming of the medullary cavity seems to have no untoward effect on the duration of union, but this finding may be slightly flattered owing to the small number of comminuted fractures in the group 'Küntscher nail with'. It is probably not due to the fact that reduction in the group 'Küntscher nail with' was often closed, for no difference in duration of union was demonstrable between open and closed reduction in the group 'Küntscher nail with'.

3. A.O.-plate osteosynthesis possibly causes some delay of union as compared with conservative treatment, but the difference is not significant. Dencker, too, found no significant difference in rate of union disturbance between a plate fixation method (no A.O.-plate) and conservative treatment. Although some devitalization of fracture fragments is inevitable also in A.O.-plate osteosynthesis, this is obviously compensated quite adequately by the stability of the osteosynthesis.

4. There is a strong indication that 'early' operation on a femoral shaft fracture prolongs the duration of fracture union.

5. Comparison of 'early' intervention, 'delayed' intervention and conservative treatment shows that 'early' intervention leads to a significantly longer duration of union than conservative treatment, whereas no such difference is observed between 'delayed' intervention and conservative treatment.

6. In the present series, open and closed fractures do not differ significantly in duration of union. It is concluded from this finding that

openness or closedness of a fracture is not an adequate criterion of soft-tissue damage.

7. Comminuted fractures and torque fractures differ in duration of union in favour of the latter. This difference should be regarded with reservation, however, in view of the many differences in composition between the two groups.

8. There is an indication that, if age influences duration of union, then this influence favours the younger patients, in whom duration of union is shorter than in the older groups.

9. With the necessary restrictions it can be observed in the present series that no exercise stability of osteosynthesis is associated with a longer duration of union than full exercise stability of osteosynthesis and than conservative treatment. This observation emphasizes the importance of the mechanical component in fracture union.

VII.8. REFERENCES

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Chapter VIII
Complications

VIII.1. INTRODUCTION

This chapter successively discusses the various complications which may occur in relation to femoral shaft fractures.

The mortality has been discussed in Chapter VI. Disorders of articular function will be discussed in Chapter X, and Chapter XII will deal with fat embolism and nerve lesions.

VIII.2. THROMBO-EMBOLIC COMPLICATIONS

Investigations made by Culver et al. (1970) have shown that in the case of pertrochanteric femoral fractures the diagnosis of thrombo-embolic processes on the basis of clinical phenomena is insufficient. Using phlebography, these authors demonstrated twice as many thromboses as had been clinically diagnosed.

No phlebography was carried out in Dencker's series and in the present series; the available data are therefore probably not representative of the thrombo-embolic disease process. This would seem to be illustrated by the fact that in the present series a thrombo-embolic process was found at postmortem in three patients, whereas the diagnosis was made during life in only one patient.

Dencker recorded a thrombo-embolic complication rate of 5%. About 10% of the patients in his series received prophylactic anticoagulant medication. Blichert-Toft and Hammer (1970) reported an incidence of 5%, while Suiter and Bianco (1971) mentioned 10%. Carpenter et al. (1970) observed a fatal pulmonary embolism in three out of 100 patients submitted to Küntscher nail osteosynthesis for femoral shaft fracture.

In the present study the term thrombo-embolic complication is defined as the occurrence of venous thrombosis, or pulmonary embolism, or both. The diagnosis was made on clinical grounds. Venous thrombosis was assumed to exist when swelling and pain in the calf occurred in association with an accelerated pulse and an increased body temperature.

The diagnosis 'pulmonary embolism' was made in the presence of acute pain in the chest, related to breathing, associated with an accelerated pulse and possibly with chest X-ray abnormalities and ECG changes.

Diagnostic problems were encountered in patients with multiple associated injuries and those with lower leg fractures.

On the basis of these criteria, a thrombo-embolic complication was recorded in 30 instances, i.e. 9.1%: pulmonary embolism in 22 and venous thrombosis in 8 cases.

The youngest patient was aged 20, and the eldest was 90 years old. The distribution over the age groups is shown in table 68.

Table 68. Distribution of thrombo-embolic complications over age groups.

Age groups	Number of patients	Thrombo-embolic complications	
		number	percentage
17–19	48	0	0%
20–29	78	5	6%
30–39	40	4	10%
40–49	36	1	3%
50–59	40	10	25%
60–69	38	5	13%
70 and over	49	5	10%

χ^2 not calculated because expected numbers were too small.

A striking feature is the high incidence in age group 50–59. A thrombo-embolic complication was found in 10 of the 40 patients in this group, i.e. 25%.

Dencker found no difference in thrombo-embolic complication rate between the different types of treatment. The distribution of thrombo-embolic complications over the methods of treatment in the present series is shown in table 69.

Table 69. Distribution of thrombo-embolic complications over methods of treatment.

Methods of treatment	Number of patients	Thrombo-emobolic complications	
		number	percentage
Conservative	90	10	11.1%
K-nail without	116	11	9.5%
K-nail with	49	5	10.2%
AO-plate	43	3	7.0%
Various osteosyntheses	7	1	14.2%

Conservatively treated cases show no markedly higher thrombo-embolic complication rate than the operatively treated cases. It is therefore doubtful that operative treatment could prevent thrombo-embolic complication, as has been presumed on the basis of the possibility of early ambulation in operatively treated cases (Böhler 1951).

The indication for prophylactic anticoagulant medication has been subject to changes in the course of the period studied. The same applies to the choice of anticoagulant. Moreover, it has been pointed out that the data on which these diagnoses are based, are probably not representative.

This is why the value of prophylactic anticoagulant medication (heparin and dicoumarin derivatives) cannot be established on the basis of the data on the present series.

VIII.3. INFECTIONS

The percentage of infections of the fracture site after operative treatment of closed fractures has fortunately been greatly reduced in the course of the past few decades. In 1919 Carlsson reported an infection rate of 25%; in 1929 Levander reported 17% (quoted by Dencker). In 1951 J. Böhler reported for the early Fifties an infection rate of 2–5% after operative treatment of closed fractures, and one of 5–10% after operative treatment of open fractures.

Dencker differentiated between soft-tissue infection and deep-seated infection; the latter involves osteitis. He observed soft-tissue infection in 14 out of 976 operatively and conservatively treated patients, i.e. 1.4%. The overall rate of deep infections in Dencker's series was nearly 5%. In the series of Suiter and Bianco (Mayo Clinic), only one infection was seen in 127 femoral shaft fractures, 42 of which were given operative treatment; this is an infection rate of 2.4% after operative treatment.

Blichert-Toft and Hammer likewise reported only one infection in 79 patients; this concerned an operatively treated fracture. Willenegger (1969) reduced the infection rate in his hospital from 4% to less than 1% by introducing separation of septic from aseptic wards. He developed an extensive system for the treatment of infections after osteosynthesis, central features of which are: leaving osteosynthesis material in situ as long as it still contributes to fracture stability, irrigation drainage with antibiotics dissolved in the irrigation fluid, and systematic antibiotic medication.

As early as 1963 McAusland and Eaton also argued in favour of leaving osteosynthesis material in situ.

The following notes can be made on the deep infections observed by Dencker: deep infection occurred in two of the 285 closed fractures treated conservatively. In one patient, non-union led to perforation of the skin, due to an underlying bone fragment, whereupon a deep infection developed which necessitated amputation. In the other patient, a lower leg amputation was performed because of gangrene of the foot after femoral shaft and tibial shaft fracture. An infection occurred in the stump and spread to the thigh, as became apparent when a femoral amputation was performed. Dencker encountered a deep infection in 32 out of 588 fractures treated by operation, i.e. 5.7%. He was unable to demonstrate a relationship with the method of osteosynthesis used.

In a series of 103 open fractures treated by various methods, Dencker observed 14 deep infections,

i.e. 13.6%! In the series of open fractures Dencker found a significant difference in infection rate between operative and non-operative treatment, the respective percentages being 21 and 3.

In the present series, soft-tissue infection was observed in 6 out of 313 fractures (329 patients minus 14 deceased patients and 2 primary amputations), i.e. 1.7%; deep infection was observed in 11 cases, i.e. 3.5%.

The six soft-tissue infections were observed after operative treatment of closed fractures: Küntscher nail osteosynthesis without reaming of the medullary cavity in 3 cases, Küntscher nail osteosynthesis with reaming in 1 case, and A.O.-plate osteosynthesis in 2 cases.

In 5 patients the wound and the underlying fracture healed after drainage and antibiotic medication. One female patient (nr. 325) suddenly died on the 48th day after the accident (cf. page 53). She had been treated by A.O.-plate osteosynthesis. The soft-tissue infection could have changed into a deep infection!

The case histories of the 11 patients in whom a deep infection developed, will be given in detail in view of the importance of this complication. This is the more important because these patients developed many other complications as well, e.g. amputation, refracture and disturbance of union. In the discussion of these complications, references can be made to the case histories presented here. The case histories of a few patients were already presented in Chapter VI, in the section on deceased patients, so that references to the appropriate page are sufficient.

1. Patient nr. 002: cf. page 51.

2. Patient nr. 042, a woman aged 63, fell from a height of about 150 cm and sustained a closed transverse femoral shaft fracture with butterfly. The patient was hypertensive. Two days after the accident a Küntscher nail osteosynthesis was performed without reaming of the medullary cavity. The osteosynthesis was not stable. After the operation she developed a staphylococcal pneumonia, probably in part as a result of costal fractures overlooked at the first examination.

A wound abscess became manifest 4 weeks after osteosynthesis. It was drained and Staphylococcus aureus was isolated from the pus. No phage typing was done. Gradually, radiological evidence of osteitis developed.

Seven and a half months after the accident the Küntscher nail was removed and a plaster spica was applied, whereupon the patient was discharged. Repeated re-admissions for drainage and fresh plaster bandage were necessary. Fracture union was achieved 18 months after the accident, but wound fistulization continued. The patient had meanwhile developed nephrolithiasis and suffered from recurrent urinary infections. She sustained a homolateral pertrochanteric fracture in a fall two and a half years after the first accident.

A follow-up more than ten years after the accident showed that there was still occasional fistulization. The patient was walking with the aid of a cane. The leg was shortened by 6 cm, and the knee was virtually ankylotic.

3. Patient nr. 043, a 23-year-old man, was riding a motor-scooter when he collided with a car and sustained a closed transverse femoral shaft fracture and concussion of the brain. Küntscher nail osteosynthesis without reaming of the medullary cavity was carried out four days after the accident. The osteosynthesis was stable. The patient developed pyrexia after the operation. He also showed transient jaundice, which remained unexplained.

Wound infection became manifest 4 weeks after osteosynthesis. Initial pus cultures yielded Staphylococcus epidermidis and Achromobacter; Staphyloccus aureus was subsequently isolated. The infection disappeared and the fracture attained bony union after 6 months. The nail was removed two years after the accident. A sequestrum was operatively removed four and a half years after the accident. The postoperative course was uneventful.

A follow-up more than nine years after the accident showed excellent anatomical and functional restoration of the limb. No further symptoms of infection had occurred. Radiological examination showed that the cavity of the sequestrum had filled almost entirely with bone.

4. Patient nr. 072, a man aged 51, drove his car against a tree and sustained an open comminuted femoral shaft fracture, a pelvic fracture and a homolateral open patellar fracture. The patient was suffering from depressions. Küntscher nail osteosynthesis without reaming of the

medullary cavity was carried out on the day after the accident. Three encircling wires were applied and patellectomy was performed. The osteosynthesis was not stable, and wire extension on a Braun splint was applied. The patient developed a Korsakow syndrome in the postoperative period. He was discharged two months after the accident and re-admitted four months after the accident to the Küntscher nail to be driven in further.

One year after the accident (patient had resumed work) he heard a cracking sound in the leg and found that walking was impossible. Upon re-admission, refracture and breaking of the Küntscher nail was found. However, there were also clinical and radiological symptoms of deep infection. Drainage was effected, and Streptococcus viridans was isolated from the pus. A few days later the broken Küntscher nail was removed and replaced by a new nail of the same diameter. Fracture union was achieved four months later (sic!). Three months later the patient made a successful suicidal attempt: he drove his car into another tree.

5. Patient nr. 127: cf. page 54.

6. Patient nr. 142, a 67-year-old man with bilateral hip-joint osteoarthritis and incipient dementia, fell in a dizzy spell and sustained a spiral femoral shaft fracture. Osteosynthesis was effected with the aid of three vitallium screws 12 days after the accident. The osteosynthesis was not stable, and the fracture fragments were found to be loose three days after the operation. Reoperation was performed one week later with the intention of applying an encircling wire.

In view of a discharge of pus, this operation was not completed. Staphylococcus aureus was isolated from the discharge. Treatment of the fracture was continued by wire extension and plaster bandage. Osteitis developed and necessitated femoral amputation five months after the accident.

The patient made a good recovery from this operation but did not succeed in learning to walk with a prosthesis; he became a wheelchair patient. He successfully underwent cholecystectomy for cholelithiasis two and a half years after the accident. A year later he suddenly died at home. The cause of death was not recorded.

7. Patient nr. 194, a man aged 58, was riding a motorcycle when he collided with a car, sustaining an open transverse femoral shaft fracture with a homolateral fracture of the tibia and tibial plateau and rupture of the popliteal artery. After vascular reconstruction, Küntscher nail osteosynthesis without reaming of the medullary cavity was carried out; the nail was inadvertently driven through the cortex of the distal fragment. The osteosynthesis was not fully exercise-stable. The lower leg fracture was likewise treated by Küntscher nail osteosynthesis. Postoperative anuria necessitated haemodialysis. Gangrene of the foot developed, and a lower leg amputation was performed. The amputation wound continued to fistulize.

Two months after the accident, femoral amputation was performed in view of continuous fistulization of the lower leg amputation wound. The femoral amputation wound likewise gave complications. Stump correction was carried out two years after the accident. Sequestrotomy was performed seven years after the accident, at which time a follow-up was made. The patient was found to walk well with a prosthesis.

8. Patient nr. 253: cf. page 50.

9. Patient nr. 300, a man aged 25, crashed his motorcycle against a tree, sustaining an open comminuted femoral shaft fracture and a fissure in the homolateral medial femoral condyle. The patient was suffering from severe diabetes mellitus. After wound toilet a wire extension was applied through the tibial condyle. Contrary to routine procedure with open fractures, no antibiotics were given. After three weeks, A.O.-plate osteosynthesis was carried out, with transplantation of autogenous cancellous bone from the pelvic crest. At operation, off-coloured fluid was observed at the fracture site; Aerobacter aerogenes was isolated from this fluid. Osteitis became manifest. Irrigation drainage was effected 12 weeks after the accident. Staphylococcus aureus was isolated from the pus. Fracture union was markedly delayed. Sequestrotomy was performed 11 months after the accident, and the osteosynthesis material was removed. Bony union was finally achieved 16 months after the accident.

At follow-up three years after the accident the patient was free from symptoms. The wound had healed. There was no radiological evidence of

osteitis. Knee flexion was limited by 40°; femoral rotation was faulty: 40° exorotation. The patient was doing fairly heavy work in a supermarket and had no complaints.

10. Patient nr. 311: cf. page 55.

11. Patient nr. 329, a man aged 40, fell from a height of 10 metres and sustained an open comminuted fracture of the femoral shaft, perilunar dislocation fracture on the left, open fracture of the distal part of the forearm with ulnar dislocation and radial head fracture on the right. The nasal bone also fractured. It was later noticed that a medial femoral neck fracture had occurred on the side of the femoral shaft fracture. The two wrist fractures were operatively treated, immediately after which A.O.-plate osteosynthesis of the femoral shaft fracture was effected. Five weeks after the accident the osteosynthesis wound discharged pus from which Aerobacter aerogenes was isolated. An irrigation system was introduced five months after the accident, and an osteoplasty with cancellous bone was carried out. Several bacteria were now isolated from the wound: Pseudomonas aeruginosa, Proteus mirabilis and Staphylococcus aureus. The two wrist fractures required re-operation, but this was contraindicated in view of the infection in the thigh.

Irrigation systems were repeatedly introduced; sequestrotomies and cancellous bone grafts were carried out. After 17 months the patient fell and sustained a refracture, for which a fixateur externe was applied. Three years after the accident the wound was still fistulizing. Fracture union had occurred. There was no question of resuming work. Partly in view of the serious functional limitation in both wrists, this will probably remain impossible!

The above case histories clearly illustrate the sad consequences of deep infection. Actually, the infection was cured in only two of the eleven patients. They were the two youngest patients, who apparently had sufficient reserves to overcome the infection. Four patients died before a cure could be attained. Amputation was necessary in two cases.

In all cases but one the infection occurred following operative fracture treatment. In the one patient with a closed fracture in whom deep infection occurred during conservative treatment (patient nr. 253), the circumstances were exceedingly unusual.

No deep infection occurred after Küntscher nail osteosynthesis with reaming of the medullary cavity. But this complication was observed in six cases after Küntscher nailing without reaming, i.e. an infection rate of 6%.

Deep infection occurred in three cases after A.O.-plate osteosynthesis, i.e. 7%.

The group 'various osteosynthesis techniques' included one instance of deep infection (patient nr. 142).

Infection occurred in seven of the 267 cases of closed fracture, i.e. 2.6% (Dencker: 3.9%).

Of the 46 open fractures, 32 were treated by osteosynthesis; deep infection occurred in four of these, i.e. 12.5% (Dencker: 13.6%).

No infection occurred in the 14 open fractures which were treated conservatively.

It is evident from the above as well as from Dencker's study that operative treatment of open femoral shaft fractures carries a substantial risk of infection. Nevertheless there can be certain indications in which the advantages of osteosynthesis outweight the risk of infection. It is useful to bear in mind, moreover, that the infection problem is a complex one, and that many factors play a role in the pathogenesis of infections in cases of femoral shaft fracture (Dencker 1963).

VIII.4. AMPUTATIONS

If an amputation is necessary in a case of femoral shaft fracture, this is usually due to severe soft-tissue injuries or a lesion of the superficial femoral artery.

Dencker described an amputation as primary when it was done more or less immediately after the accident, and as secondary when it was done in the course of the period of illness following the accident.

Buck-Gramcko (1954) listed four amputations (all primary) in a series of 103 femoral shaft fractures. The indications were: lesion of the superficial femoral artery in two cases, rupture of the popliteal artery in one, and a circular soft-tissue injury of the thigh in one case.

Blichert-Toft and Hammer (1970) had one case

of amputation in their series of 82 femoral shaft fractures. This was a patient with a lesion of the superficial femoral artery.

Dencker (1964) recorded three primary amputations: one because of a lesion of the superficial femoral artery and two in view of crushing of the lower leg. He listed 18 secondary amputations, i.e. 1.8%. The indications were: lesion of the superficial femoral artery in two, non-union in four, deep infection in eleven cases, and severe haemorrhage during corrective osteotomy in one case (a haemophiliac patient).

Four amputations were performed in the present series: two primary and two secondary amputations. Deep infection necessitated the latter two. The case histories of these patients (nrs. 142 and 194) were presented in section VIII.3. The case histories of the patients with a primary amputation were as follows.

1. Patient nr. 304, a man aged 40, skidded his car into a tree. The car caught fire and the patient sustained deep burns of 45% of the body surface. He also sustained a comminuted fracture of the left femoral shaft and an open fracture of the homolateral fibula. Deep circular burns of the entire left thigh necessitated amputation on the sixth day after the accident. After a highly critical course of illness the patient finally made a good recovery and learned to walk well with a prosthesis.
2. Patient nr. 334, a man aged 63, was riding a moped when he collided with a car, sustaining a virtually circular soft-tissue injury of the thigh with crushing of the homolateral knee and lower leg. There was a lesion of the extensor apparatus. A few years earlier this patient had undergone proctectomy for carcinoma of the rectum. Prior to the accident he had symptoms of intermittent claudication in the leg involved. Avitality of the lower leg necessitated femoral amputation on the day of the accident. The patient learned to walk well with a prosthesis.

The present series shows a conspicuous absence of amputations for a lesion of the superficial femoral artery. There were three patients with such a vascular lesion. In all reconstruction was successful (cf. Chapter XII).

The period covered by Dencker's series preceded the period studied in the present series by ten years. Failure of reconstruction of the femoral artery in Dencker's series and its success in the present series could perhaps be attributed to the progress made in the field of vascular surgery during the intervening ten years. On the other hand, an increase in the number of primary amputations in patients with femoral shaft fractures is to be taken into account in view of the increased number and severity of traffic accidents.

VIII.5. COMPLICATIONS RELATED TO KÜNTSCHER NAIL OSTEOSYNTHESIS

Some complications typically related to the use of a Küntscher nail are:

1. Jamming of the nail.
2. Splitting of bone while the nail is being inserted.
3. Perforation of the cortex.
4. Spontaneous proximal or distal migration of the nail.
5. Bending or breaking of the nail.

Several publications have been devoted to one or several of these complications (Lottes and Key 1953; Koslowski and Weller 1962; Dencker 1964; Wickstrom and Corban 1967; De Belder 1968).

Jamming of the nail was recorded in three cases in the present series. The medullary cavity had not been reamed. In one case the nail was sawn off above the great trochanter; in the other two cases it could be removed, be it with considerable difficulty, and replaced by a thinner nail.

Splitting of bone while the nail was being driven in was observed in six cases: the distal fragment fissured in five, and the proximal fragment in one. Two cases involved Küntscher nail osteosynthesis without reaming; in four cases the fissure occurred during or after reaming. In one case the Küntscher nail used had a diameter 0.5 mm less than that of the last used drill. In the remaining cases the difference between drill and nail was 1 mm. The occurrence of longitudinal fissures posed no serious problems, but in a number of cases the desired stability was not achieved.

Perforation of the cortex occurred in two cases. The case history of one patient (nr. 194) was given

in section VIII.3. It is improbable that in this patient the perforation gave rise to the infection. One should beware of this complication in the case of marked antecurvation of the femur.

Spontaneous migration of the nail was observed only once in the present series. In this case the Küntscher nail was too short and too thin. At ambulation the patient noticed that the nail gradually came to protrude further from the trochanter. The nail was driven in again and secured with a metal wire.

In two other patients the Küntscher nail had to be driven in further, but in these cases the nail had not been inserted far enough at the first operation, and pain at the site of the tip of the nail had resulted.

In the present series, bending or breaking of the nail was observed only with Küntscher nail up to 10 mm in diameter. In Dencker's series, in which V-shaped Küntscher nails of small diameter were mostly used, bending occurred in 16% and breaking in 2% of cases.

In the present series the nail bent in three and broke in two cases. This complication was no longer observed with Küntscher nails exceeding 10 mm in diameter.

The complication rates vary rather widely, dependent on the technique used and the experience of the operating surgeon.

It can be maintained that, in principle, the above described complications are preventable. Careful scrutiny of radiographs for longitudinal fissures, cautious reaming technique, the choice of nails of appropriate length and diameter, and prudence in their insertion – all these are factors of importance in this respect.

VIII.6. COMPLICATIONS RELATED TO WIRE EXTENSION

In the conservative treatment of femoral shaft fractures, skeletal traction is as a rule employed. This can be applied at three sites: supracondylar level, tibial tuberosity, and calcaneus.

Watson-Jones (1952) and L. Böhler (1957) rejected supracondylar wire extension in view of the occurrence of damage to the extensor apparatus of the knee, and arthritis of the knee-joint. They marked the tibial tuberosity as a safe site of wire extension. Possible complications at this site are: infection, severance of the wire, and injury to the peroneal nerve.

Dencker listed 25 cases of wire infection, i.e 3%; unmistakable osteitis developed in four cases. In one case, supracondylar wire extension was followed by purulent arthritis, ending in ankylosis.

Dencker listed 21 cases of severance of the wire, and two cases of transient dysfunction of the peroneal nerve. He found a significant difference in the rate of complications between supracondylar and tibial tuberosity wire extensions (9% and 3%, respectively).

In 294 instances a wire extension was employed in the present series. It was of the supracondylar type in 39, passed through the tibial tuberosity in 253, and through the calcaneus in 2 cases. A complication occurred in 8 instances (2.7%): infection in 6 cases, wire severance in 1 and transient dysfunction of the peroneal nerve in 1 case.

In no case did infection of the bone occur.

In view of the findings in the literature, the tibial tuberosity would seem to be the site of choice for wire extension in the case of femoral shaft fracture. The number and severity of complications of skeletal traction prove to be limited.

VIII.7. REFRACTURES

The term refracture is used here to refer to a fracture which occurs at the site of an existing fracture during or shortly after the latter's treatment.

Dencker listed a refracture in 20 of the 837 femoral shaft fractures of which he studied union, i.e. 2.4%. Of these 20 refractures, 17 occurred within a year of the accident. Dencker found no correlation with the type of treatment or with the openness or closedness of the original fracture.

The resorption sometimes observed around encircling wires has been held responsible for refracture by some authors (Olsson 1949; Arnesen 1951; Stören 1958). Stören went so far as to use the designation 'encircling fractures'.

Hartmann and Brav (1954), reporting from a military rehabilitation centre, listed 12 refractures in 135 patients with a femoral shaft fracture, i.e. 8.9%. The original fracture was often a bullet wound, and this may possibly explain the large percentage of refractures. They maintained that refracture could have been prevented in two out of three patients if ambulation had been started more cautiously.

Seimon (1964) observed 21 refractures in a series of 476 femoral shaft fractures, i.e. 4%; his series, however, included children as well as adults. In his opinion many refractures during conservative treatment can be prevented by adhering to a minimal limit of 12 weeks' immobilization.

Richon et al. (1967) observed 15 refractures in 120 A.O.-plate osteosyntheses, i.e. 12.5%. Their series also included shaft fractures other than femoral. In some cases the osteosynthesis material was apparently removed prematurely, but refractures were also observed as a result of insufficient restoration of the architecture of the long bone, specifically after osteosynthesis of femoral shaft fractures with the aid of two plates applied at an angle of 90°. In view of this high refracture rate, Richon et al. abolished the use of this so-called 'double plate osteosynthesis'.

In the present series, 15 refractures were found among 300 femoral shaft fractures (329 patients minus 4 amputations and 25 deaths before refracture could occur). The refracture rate in the present series was therefore 5%.

Three refractures occurred after Küntscher nail osteosynthesis without reaming of the medullary cavity. One patient (nr. 072) was already discussed in section VIII.3. The second was patient nr. 005, with refracture after removal of the Küntscher nail six months after the accident. The progress of union had been misinterpreted at radiological examination. Treatment consisted of reduction and application of a spica plaster. A serious delay in union occurred. Full union was not achieved until after 14 months. The result was poor functional and anatomical restoration. The third patient (nr. 094) put his full weight on the fractured leg 68 days after the accident. The leg gradually bent in varus position. Radiological examination disclosed bending of the Küntscher nail, which was then removed. A tibial tuberosity wire extension was applied, which was later replaced by a plaster spica. Fracture union was complete seven months after the accident, but with 10° varus deformity. Functional restoration was complete. In the first and the second of these three cases, one or more encircling wires were applied at osteosynthesis. Cerclage was used in a total of 17 cases of Küntscher nail osteosynthesis. The number of refractures in the present series is too small to substantiate Stören's conclusion that the encircling wires were responsible or partly responsible for the refractures.

No refractures were observed after Küntscher nail osteosynthesis with reaming of the medullary cavity. Undoubtedly this may be attributed to the use of nails of larger diameter (for strength substantially increases with diameter).

Three refractures occurred after A.O.-plate osteosynthesis. One occurred in patient nr. 329, 18 months after the accident. This patient was discussed in detail in section VIII.3 (page 77). In the other two patients the refracture occurred while the plate was still in situ.

1. Patient nr. 266, a woman aged 80, missed a step descending stairs and sustained an oblique femoral shaft fracture. A.O.-plate osteosynthesis was effected two days after the accident. Refracture occurred when the patient walked with canes (partial weight bearing) eight and a half months after the accident. Treatment consisted of application of a new plate and a cancellous bone graft. Fracture union in anatomical position was attained 14 months after the accident. The functional result was excellent.
2. Patient nr. 322, a 24-year-old man with oligophrenia and marked myopia, was a pillion passenger on a moped which collided with a car. He sustained a closed comminuted fracture of the left femoral shaft and a closed homolateral lower leg fracture, along with a pertrochanteric fracture of the right femur. Three years earlier, a supracondylar fracture of the right femur had been treated by osteosynthesis after a similar accident. On the 4th day after the accident the femoral shaft fracture was treated by plate osteosynthesis, and the pertrochanteric fracture by 130° plate osteosynthesis. Some four months after the accident the patient 'went through the left leg' while walking with canes. Radiological examination revealed that fracture and plate had both 'broken'. Another plate osteosynthesis was carried out, and a cancellous bone graft was done. Fracture union was achieved seven months after the accident,

Table 70. Survey of patients in whom refracture occurred during conservative treatment.

Patient nr.	Age	Sex	Accident type	Fracture type	Open or closed	Day of refracture; place	Treatment	Duration of union
006	21	m	traffic	transverse + butterfly	closed	76th day, hospital	K-nail without	unknown
048	46	m	traffic	transverse + butterfly	closed	90th day, hospital	plaster spica	6 months
080	68	m	traffic	transverse	closed	155th day, hospital	plaster spica	9 months
156	53	m	traffic	transverse + butterfly	closed	147th day, home	plaster spica	11 months
179	17	m	traffic	transverse + butterfly	closed	82nd day, home	K-nail with	8 months
183	27	m	work	comminuted	closed	116th day, home	wire extension	6 months
249	18	m	traffic	transverse	closed	70th day, hospital	wire extension	5 months
258	17	m	traffic	transverse	closed	85th day, hospital	AO-plate	5 months
277	34	m	traffic	comminuted	closed	91st day, hospital	AO-plate	6 months

with good functional result.

Radiological examination one year after the accident revealed that the 130° plate had broken, while the pertrochanteric fracture had meanwhile united.

Although in the present series no refractures occurred after removal of the A.O.-plate, this complication did occur in the course of the years following the period studied; this is in agreement with the observations of Richon et al.

Refractures were most frequently observed in the course of conservative treatment: in 9 out of 91 conservatively treated fractures, i.e. 9.9%.

Table 70 presents a survey of the patients and of a number of relevant data.

Table 70 shows that in particular young patients with bending fractures are liable to refracture during the 10th-12th week of conservative treatment. A possible explanation lies in the subjective fracture healing attained during this period, which makes the patient too daring in exposing the leg to weight bearing.

Treatment of refracture during conservative treatment as a rule posed no problems. Bony union could be achieved within a reasonable period of time. In one patient (nr. 048) the duration of inability to work was very long: 24 months. A follow-up nine years after the accident revealed 40° limitation of knee flexion in this patient. The remaining patients in table 70 made complete functional recoveries, so far as could be established.

Refracture means an increased duration of illness and inability to work. Occasionally, osteosynthesis material was removed without adequate radiological verification of fracture union. In other cases, youthful exuberance on the part of the patient played a role.

VIII.8. DISTURBANCES OF UNION

Disturbances of union is a term which encompasses all cases in which delayed union and non-union occurred. The arbitrary limit of 8 months to separate normal from abnormal duration of union has already been discussed in Chapter VII.

Little or no value is attached to general factors in the aetiology of delayed union (Charnley, Küntscher). But an important role is assigned in this respect to local factors such as marked dislocation and distraction, infection and circulatory disturbances (Dencker).

Watson-Jones (1952) expressed as his opinion: 'Non-union of fractures is due to failure of surgeons much more than to the failure of osteoblasts. With few exceptions, it is an avoidable complica-

tion'. He mentioned complete immobilization of the fracture fragments as an absolute prerequisite for normal union.

Trueta and Cavadias (1955) demonstrated the importance of an intact nutrient artery in the healing of fractures of the long bones in test animals. They assumed that this also applies to human individuals, and that insertion of an intramedullary nail leads to delayed union.

Küntscher (1970) refuted this, and ascribed delayed union to inadequate immobilization.

It is very likely that a correlation exists between the severity of the soft-tissue injury and the duration of union. But since the soft-tissue injury cannot be quantified, it will be virtually impossible to demonstrate this correlation. Studies of the literature on delayed union and non-union give information which is not readily interpretable. Different criteria are applied in different studies, the series discussed differ in composition, and disparate types of treatment are involved (Watson-Jones 1952; Boyd et al. 1961).

Dencker found 124 cases of delayed union and non-union in a series of 837 femoral shaft fractures, i.e. 14.8%. He found no relationship to age, sex, and shaft segment involved. In the group treated only by cerclage, delayed union was significantly more frequent than in conservative treatment, Küntscher nail osteosynthesis without reaming of the medullary cavity, and plate osteosynthesis (not A.O.-plate osteosynthesis). There were no significant differences between the three last-mentioned types of treatment.

The cause of the disturbance of union was identified by Dencker as deep infection in one-third of cases, and redislocation of the fracture after osteosynthesis is another one-third of cases.

For the present series, calculations concerning fracture union were made with regard to 261 cases, which included 16 instances of delayed union and one case of non-union, i.e. 6.6% (table 56, page 64). To these should be added 15 fractures of the 'unclassifiable' group of which data on union were available, and which included two cases of delayed union. In this manner the delayed union rate in the present series amounts to 6.9%. The distribution of the disturbances of union over the various methods of treatment is shown in table 71.

The percentage of 13.3 for the 'unclassifiable' group is inconclusive because of the small number of patients and the heterogeneous composition of the group.

Table 71. Distribution of disturbances of union over the various methods of treatment.

Methods of treatment	Number of fractures	Disturbances of union number	percentage
Conservative	82	4	4.8%
K-nail without	97	7	7.2%
K-nail with	45	1	2.2%
AO-plate	37	5	13.5%
'unclassifiable'	15	2	13.3%

The large percentage in the group treated by A.O.-plate osteosynthesis does merit further analysis.

The case histories of the 19 patients with disturbed union will be briefly reviewed.

The case histories of two of the four patients given conservative treatment (patients nrs. 080 and 156) were already given in section VIII.7. The two remaining case histories are the following.

1. Patient nr. 047, a woman aged 75, stooped and sustained a closed oblique femoral shaft fracture, treated by supracondylar wire extension on a Braun splint and plaster bandage. Traction was discontinued after three and a half months, and patient was prescribed bed rest at home. Radiological union was seen nine months after the accident. Eight years after the accident the patient sustained a contralateral femoral neck fracture, from which she recovered also.

2. Patient nr. 052, a woman aged 50, was riding a bicycle which was hit from the rear by a car. She sustained a closed transverse femoral shaft fracture with butterfly, a fracture of the shaft of the homolateral humerus, and severe laceration of the skin of the contralateral lower leg. The femoral shaft fracture was treated by supracondylar wire extension on a Braun splint and plaster bandage. Radiological examination showed that the triangular fragment (butterfly) was in transverse position between the two fracture fragments. Closed reduction was carried out two months after the accident. Traction was discontinued after three and a half months, and a plaster spica was applied. Fracture union was achieved ten months after the accident.

Of the seven patients treated by Küntscher nail osteosynthesis without reaming, patient nr. 005 was discussed in section VIII.7, while detailed histories of patients nrs. 042, 072 and 127 were presented in section VIII.3. The case histories of the three remaining patients follow here.

1. Patient nr. 065, a 41-year-old man, was riding a motorcycle and collided with a car, sustaining an open mandibular fracture, a closed fracture of the wrist and a closed transverse femoral shaft fracture with butterfly. Open Küntscher nail osteosynthesis without reaming of the medullary cavity was carried out six days after the accident. The triangular fragment proved to consist of two parts, one of which was removed because it had become detached from the soft tissues. Union was greatly delayed: full union was not achieved until 14 months after the accident.

2. Patient nr. 093, a man aged 71, crashed his moped against a tree. He sustained a homolateral clavicular fracture and an oblique femoral shaft fracture with butterfly, (available data did not show whether the fracture was open or closed). Open Küntscher nail osteosynthesis without reaming of the medullary cavity was carried out on the day after the accident. The Küntscher nail used had a diameter of 9 mm, although the medullary cavity in this patient was extremely wide. Radiological fracture union was observed after 11 months.

3. Patient nr. 115, a man aged 55, was riding a bicycle when he collided with a car, sustaining a closed transverse femoral shaft fracture with butterfly. Küntscher nail osteosynthesis without reaming of the medullary cavity was carried out on the day of the accident. The osteosynthesis was not stable. Postoperative pulmonary embolism was treated with anticoagulants. Severe rectal bleeding occurred during this medication. Eleven months after the accident the Küntscher nail was removed without sufficient radiological verification. After this operation the patient complained of pain in the leg when walking. Radiological examination showed that the nail had been prematurely removed: there was inadequate bone remodelling. An inlay graft was applied, and immobilization was effected by means of a plaster spica. Fracture union was achieved 18 months after the accident.

The case history of the one patient in whom a disturbance of union occurred after treatment by Küntscher nail osteosynthesis with reaming of the medullary cavity, is as follows.

1. Patient nr. 227, a 46-year-old man, was hit by a passing car while he was a bystander at the site of a car accident. In addition to costal fractures he sustained a comminuted femoral shaft fracture with severe soft-tissue injury (a large part of the vastus medialis muscle was missing). Open Küntscher nail osteosynthesis with reaming of the medullary cavity was carried out immediately. A large bone fragment which had become detached from the soft tissues, was removed. The medullary cavity was reamed to a diameter of 14 mm, and the Küntscher nail inserted had a diameter of 13 mm. The osteosynthesis was not stable. After the operation the patient developed fat embolism with petechiae, from which he recovered. Gradually, true non-union with sclerosis of the bone ends became apparent. In fact this patient was the only example of marked non-union in this series.

The patient refused re-operation in spite of repeated urging. He maintained that he could walk well enough with a cane. He did not resume work and continued to receive compensation from the insurance company of the other party. He wished to postpone re-operation until a definite arrangement could be made with this insurance company! Re-nailing was done four years after the accident, and a cancellous bone graft was applied at the same time. Adequate fracture union was achieved eight months after this operation. The patient still had not resumed work five years after the accident. Anatomical and functional results were good. There was 10° limitation of knee flexion.

Of the five patients treated by A.O.-plate osteosynthesis, patient nr. 266 was discussed in section VIII.7, and patients nrs. 300, 311 and 329 in section VIII.3. The case history of the remaining patient follows here.

1. Patient nr. 247, a man aged 33, was riding a moped when he collided with a car, sustaining an open transverse femoral shaft fracture with butterfly. A.O.-plate osteosynthesis was effected three weeks after the accident. Fracture union was achieved nine months after the accident.

The case histories of the two patients in the 'unclassifiable' group are as follows.

1. Patient nr. 030, a 29-year-old woman, was a

pillion passenger on a motorcycle which collided with a tractor. The injuries were: closed transverse femoral shaft fracture with butterfly, closed fracture of the neck of the homolateral femur, and open fracture of the homolateral patella and forearm. Osteosynthesis with a Lane plate was carried out five days after the accident. The triangular fragment was removed because it had become detached from the soft tissues. Osteosynthesis of the femoral neck was unsuccessful, and non-union followed. Union of the femoral shaft fracture was delayed, and was not achieved fully until 14 months after the accident.

2. Patient nr. 097, a man aged 26, was riding a motorcycle when he collided with a car. In addition to a lesion of the left brachial plexus and symphysiolysis there were several severe injuries of the left leg: open comminuted femoral shaft fracture, open patellar fracture, open lower leg fracture and open fracture of the talus. Radiological examination of the femur revealed that a few large fragments were missing. The patient was initially treated by wire extension through the tibial tuberosity. Five days after the accident the continuity of the femoral shaft was restored with the aid of a 12 cm long graft taken from the patient's right fibula. A plaster spica was applied and continued for seven months. Femoral shaft fracture union was achieved 12 months after the accident. Triple arthrodesis of the ankle-joint was subsequently carried out.

At follow-up nine and a half years after the accident the patient was walking very well. The left leg was 1 cm shorter, and knee flexion was limited by 30°. The arthrodesis was successful, the ankle being free from pain. The patient was declared entirely unfit to work because of total paralysis of the left arm.

A study of the above case histories makes it possible to distinguish a number of factors which have contributed to the disturbances of union discussed. Deep infection was involved in 6 cases, and refracture in 4 cases; in two patients (nrs. 227 and 097) very severe local soft-tissue injury at the fracture site led to a defect fracture. In two other patients (nrs. 065 and 030), removal of a triangular fragment or part of it may have had an untoward effect. The high rate of disturbances of union in the group of fractures treated by A.O.-plate osteosynthesis may have been caused by the relatively large number of deep infections in this group.

VIII.9. OTHER COMPLICATIONS

Various other complications which occurred in the present series will be reviewed, but a detailed analysis of these complications is not opportune.

Bronchopneumonia occurred in 13 of the 315 patients (329 minus 14 early deaths).

Urinary infections were diagnosed in 19 of the 315 patients (329 minus 14 early deaths). Nephrolithiasis occurred in 9 patients, either during treatment or in the interval between discharge from hospital and the first follow-up.

A cytomegalovirus infection was observed during treatment in 3 patients.

Severe decubitus was mentioned in 11 case histories.

Severe rectal bleeding occurred as a result of anticoagulant medication in one case. Jaundice was observed in 2 cases following administration of decholine in view of a fat embolism.

Removal of osteosynthesis material led to a complication in 5 out of 125 such interventions, i.e. 4%. The complication was either superficial wound infection or bleeding, and always responded to treatment.

Gauze was left in the operation wound in 2 of the over 300 operations in this series. This was established at the first radiological follow-up, and the gauze was operatively removed.

A complication occurred in three of the more than 400 anaesthesias given to the patients in this series. In 2 cases this was severe transient hypotension resulting from hypovolaemia; oesophageal intubation was involved in 1 case. These complications were identified as such and adequately treated.

VIII.10. SUMMARY AND CONCLUSIONS

Deep infection of the fracture area is the red thread which runs through this chapter on complications. It occurred in 11 cases, and in all but one of these it followed osteosynthesis. Only 2 patients made a good recovery. Amputation was necessary in 2 other cases, and in 3 cases the infection was an important factor contributing to death.

No deep infection occurred in patients treated by Küntscher nail osteosynthesis with reaming of the medullary cavity. The majority of these osteosyntheses were effected by a closed procedure.

In the present series, operative treatment of open fractures proves to have carried a considerable risk of infection (12.5%). No deep infection was observed in the conservative treatment of open fractures.

The diagnosis 'thrombo-embolic disease process' was made on the basis of clinical symptoms in some 9% of patients. There was no difference in the rate of this complication between operatively and non-operatively treated patients.

Refractures occurred in 5% of cases in the present series. Two causes came to the fore:

* removal of osteosynthesis material without adequate fracture union;
* too daring use of the leg during conservative treatment.

Particularly during the 10th–12th week of conservative treatment of femoral shaft fractures, there is a risk of refracture particularly in youthful patients.

Femoral amputation was necessary in 4 cases in the present series: because of very severe soft-tissue injury in 2 cases, and because of deep infection in the other 2 cases. No amputation was necessitated by associated lesions of the superficial femoral artery.

A number of complications typically seen in Küntscher nailing of femoral shaft fractures, are discussed in this chapter.

The tibial tuberosity is to be preferred to the supracondylar region as the site of predilection for wire extension. In the present series the number of complications due to wire extension was small.

In the present series there was in fact only one instance of manifest non-union. Techniques currently available for the treatment of delayed union are so good that non-union is on its way to becoming a great exception.

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Chapter IX
Methodology of follow-up

IX.1. INTRODUCTION

In a follow-up study of patients with an affection of the suspensory and locomotor apparatus, the patient should be personally examined. Inquiries by questionnaire give inadequate and unreliable information. Preparatory to his follow-up study of femoral shaft fractures, Dencker carried out a pilot study in the vicinity of his home town. The discrepancy between data obtained by questionnaire and his personal findings was so great that he decided to examine all patients personally, either at home or in an out-patient clinic. In a country such as Sweden, a decision of this kind has farreaching consequences: Dencker travelled some 50.000 miles in the course of two years! He visited about 500 patients at their homes, and the remaining patients came to an out-patient clinic near their place of residence.

Chung (1971) likewise stressed the importance of a complete follow-up, and he suggested methods of locating missing patients. His suggestions mainly concerned the situation in the United States of America.

Dencker attained a very large percentage of personally examined patients. Of the 992 patients with 1003 femoral shaft fractures, 94 died in hospital and 90 during the interval between discharge from hospital and follow-up. Of the 808 surviving patients, he personally examined 773, i.e. 95.5%. On 11 others he obtained information in writing or by telephone, and the remaining 24 patients could not be located. In Dencker's series the interval between accident and folluw-up ranged from 4 to 8 years.

Blichert-Toft and Hammer examined 64 out of 72 surviving patients, i.e. 89%. The follow-up period ranged from 6 months to 10 years and averaged 5 years. In the remaining series available for comparison, no extensive follow-up study was attempted.

In the present series the circumstances favoured a follow-up study in that a small district was involved. Home visits were deliberately avoided because they precluded a radiological examination.

IX.2. METHOD OF LOCATING PATIENTS

A standard letter was addressed to each patient in which the purpose of the study was explained and he (she) was asked to visit the out-patient clinic at a specified hour on a specified day. Enclosed was a stamped and addressed return envelope which the patient could use to report whether or not he (she) could report at the time stated. If he was unable to come at the time stated, a suitable time was arranged with him.

When there was no reply to this letter, a second letter of the same kind was sent. When this, too, remained unanswered, the correctness of the address was checked with the civil registry office of the place of residence. In a few instances, an appeal was made to the central civil registry office in The Hague. The information thus obtained was as a rule very valuable. In a number of instances it was thus established that the patient had meanwhile died. When patients had moved to another municipality, their correct addresses were obtained there.

When a letter to the correct address likewise remained unanswered, a personal letter was sent. This was nearly always sufficient to establish

contact. In a few cases, however, the reason for the lack of response had to be established in a telephone conversation with the patient or with his neighbours.

When a patient had moved abroad, information could sometimes be obtained via his family doctor or his successor. In some cases it was necessary to telephone, in a given place, all people of the same name as the patient. The purpose of the call was explained and cooperation was requested. This often yielded the necessary information on the patient's address or his having moved abroad. By these various means, all surviving patients could finally be traced!

IX.3. PATIENTS NOT EXAMINED

Table 72. Survey of patients who died during the interval between discharge from hospital and follow-up.

Patient nr.	007	015	019	032	037	040	041	060	062	072	073
Age at accident	71	73	62	81	66	82	73	81	68	51	76
Sex	f	f	m	f	m	m	m	f	m	m	f
Years until death	4½	5	9½	5½	8	7	5	2	7	1½	9
Cause of death	?	?	gastric carcin.	cardiac failure	?	colon carcin.	?	mamma carcin.	?	suicide	cereb vascu accid
Pre-existent disease	apo-plexy	hyper-tension	none	diabetes	none	none	parox. tachy-cardia	many	none	depres-sive	none
Treatment*	C	C	C	C	C	K	K	K	K	K	C
Deep infection	no	no	no	no	no	no	no	no	no	no	no
Walked again	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Death related to accident or fracture	no	no	no	no	no	no	no	no	no	no	no

Patient nr.	165	173	174	198	229	238	241	244	258	311	315
Age at accident	72	72	45	75	81	84	61	92	17	84	58
Sex	f	m	m	f	f	f	m	m	m	f	m
Years until death	3½	5	1½	4	3	5	¾	2	3	1	1
Cause of death	myoc. inf.	myoc. inf.	suicide	?	?	?	suicide	broncho-pneu-monia	accident	pyelo-nephr-itis	pulm ary carci
Pre-existent disease	heart dis.	none	none	none	none	none	none	none	none	none	osteo poro
Treatment*	K	C	K	C	D	C	K	C	AO	AO	AC
Deep infection	no	no	no	no	no	no	no	no	no	yes	no
Walked again	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes
Death related to accident or fracture	no	no	no	no	no	no	no	no	no	yes	no

* abbreviations used for methods of treatment: C = conservative treatment
K = Küntscher nail osteosynthesis
AO = AO-plate osteosynthesis
D = various other techniques of osteosynthesis

Of the 329 patients with 335 femoral shaft fractures, 29 died in hospital or in a nursing-home; 35 others died during the interval between accident and follow-up. At the time of the follow-up study, therefore, 265 patients were alive. Of these, 251 patients were personally examined, i.e. 95% of the surviving patients. The remaining 14 patients could not be personally examined in the out-patient clinic, but information on them was obtained in writing or by telephone. These patients will be briefly discussed and then eliminated from this study.

For the patients examined, the mean interval between accident and follow-up was 54 months (4½ years), the range being from 2 years to 14½ years.

The 29 patients who died in hospital or in a nursing-home were discussed in Chapter VI (Mortality).

The relevant data on the 35 patients who died during the interval between discharge from hospital and follow-up, are summarized in table 72.

)77	080	084	093	111	113	115	120	127	140	142	158	160
75	68	40	71	33	68	55	76	73	88	67	72	82
m	m	m	m	f	f	m	f	m	f	m	m	f
10½	6	6½	6½	2½	7	3	8	1	1	3	3½	2
›ncho-	?	?	pneu-	pneu-	broncho-	myocar-	?	pyelo-	?	myoc.	rectal	?
;u-			monia	monia	pneu-	dial		nephr-		inf.	carc.	
nia					monia	infarc.		itis				
nen-	demen-	none	none	epil.	demen-	none	demen-	heart	heart	demen-	heart	urin.
	tia			demen-	tia		tia	dis.	dis.	tia	dis.	incon-
				tia								tin.
C	C	K	K	K	K	K	C	K	K	K	K	C
no	no	no	no	no	no	no	no	yes	no	yes	no	no
yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	amput.	yes	yes
no	no	no	no	no	no	no	no	yes	no	no	no	no

Dencker (1963) found from experience that it was difficult to obtain exact information on the validity of the deceased patient's leg from his relatives. Similar experience was gained in the present study. Occasionally, relatives were approached in writing or by telephone, but the information obtained in this manner was always very limited. The cause of death was as a rule established via the family doctor. When the patient had died in a hospital, the cause of death could often be found in the hospital records.

The penultimate line in table 72 indicates whether or not the patient resumed walking during the interval between discharge and death. More detailed information is not available.

Perusal of table 72 shows that a relationship between death and the femoral shaft fracture existed in two patients. The case histories of these two patients (nrs. 127 and 311) are presented in Chapter VI. One other patient (nr. 142) became a wheelchair patient after amputation because of infection.

As expected, most patients who died during the interval were of advanced age. But there are a few young patients in this category. Patient nr. 258, a boy aged 17, had a fatal moped accident three years after the accident in which he sustained the femoral shaft fracture. Another young patient who died was nr. 111, a 33-year-old female epileptic (suffering from epileptic dementia). She aspirated during a seizure, and died of pneumonia.

Three patients (nr. 072, a man aged 51; nr. 174, a man aged 45; nr. 241, a man aged 61) committed suicide. The relatives denied any relationship to the accident.

There remain the 14 patients not personally examined. The information obtained on these patients will be briefly discussed.

1. Patient nr. 006, living in Germany. Initially, the femoral shaft fracture was conservatively treated. After refracture, Küntscher nail osteosynthesis without reaming of the medullary cavity was carried out. When contacted by telephone 14 years after the accident, the patient reported that he was free from symptoms and working in a garage (which he owned). He remembered having resumed work seven months after the accident.

2. Patient nr. 045, a man aged 22, was treated by Küntscher nail osteosynthesis without reaming, six days after the accident. He was transferred to another hospital with a plaster spica 31 days after the accident. When contacted by telephone 12½ years after the accident, the patient reported to be free from symptoms and working as a touring-coach driver. He could not remember when he had resumed work.

3. Patient nr. 051, a woman aged 59, was treated conservatively. When contacted by telephone 12½ years after the accident she reported that her leg was usable. She had a pseudarthrosis of a homolateral femoral neck fracture, which had meanwhile been effectively treated by operation elsewhere. The leg was shortened, and patient ascribed this to a disturbance in the union of the hip fracture.

4. Patient nr. 059, a man aged 32, was treated by Küntscher nail osteosynthesis without reaming of the medullary cavity. When contacted by telephone 11 years after the accident, he reported to be free from symptoms. He had resumed his work as a lawyer three months after the accident.

5. Patient nr. 066, a woman aged 30, was conservatively treated. After ten weeks' traction she was transferred to another hospital with a plaster spica. Fracture union was achieved after four months, but with 3 cm shortening and 20° varus angulation. Twelve years after the accident the patient wrote that she was doing her domestic work free from symptoms. The leg became painful after a long walk. She had not noticed the angulation. The knee-joint caused no symptoms, specifically no hydrops; but knee flexion was slightly limited. She had resumed her work as a nurse 6 months after the accident.

6. Patient nr. 067, a woman aged 22, was treated by Küntscher nail osteosynthesis without reaming of the medullary cavity two days after the accident. She was transferred to another hospital 25 days after the accident. Ten years after the accident she wrote that she was doing her domestic work free from symptoms.

7. Patient nr. 125, a woman aged 63, was suffering from paranoid dementia. The femoral shaft fracture was treated by Küntscher nail osteosynthesis without reaming. The patient was unmanageable in hospital, and 8 days after the accident she was discharged at her own request, with a plaster spica. She never reported for a follow-up, and nine years after the accident she refused to admit the visiting investigator. Her husband reported that the patient had removed the plaster bandage immediately after her return home from the hospital. She was walking about three weeks after the accident. According to the husband the patient never complained about the leg.

8. Patient nr. 130, a woman aged 74, was treated by Küntscher nail osteosynthesis without reaming 5 days after the accident. Nine years after the accident the patient was in a nursing-home, demented and quite extinguished. At a visit to this patient a biologically very old woman was found, with whom no contact could be established. The medical superintendent of the nursing home reported that the patient had been able to walk quite well.

9. Patient nr. 155, a woman aged 23, was treated by Küntscher nail osteosynthesis without reaming of the medullary cavity on the day of the accident. Eight years after the accident the patient wrote that she had moved to Germany and was doing her domestic work free from symptoms. She had resumed her work as a salesgirl after the accident, but could not remember exactly when.

10. Patient nr. 159, a boy aged 17, was treated by Küntscher nail osteosynthesis without reaming eight days after the accident, and transferred to another hospital 17 days after the accident. When contacted by telephone seven and a half years later, the patient reported that he had fully resumed his work in agriculture. He was free from symptoms and found his leg extremely well healed.

11. Patient nr. 161, a man aged 21, was treated conservatively. The patient was found to have moved to England, but his mother reported that he was entirely free from symptoms and doing heavy work in a shipping-yard. She did not know exactly when he had resumed work.

12. Patient nr. 169, a man aged 37, was treated by Küntscher nail osteosynthesis without reaming of the medullary cavity, one day after the accident; a hip dislocation and an acetabular fracture were reduced at the same time. Postoperative treatment was partly given elsewhere. Eight and a half years after the accident the patient reported by telephone that he was completely free from symptoms. He was too busy to report at the hospital in person. He had noticed that the leg in question showed exorotation.

13. Patient nr. 183, a man aged 27, was treated conservatively. When contacted by telephone seven years after the accident, he reported that his leg was quite serviceable. He was very busy as a milk-lorry driver and saw no reason to report at the hospital in person.

14. Patient nr. 222, a man aged 19, was treated conservatively. Fracture union was achieved after three months. Four years after the accident the patient reported by telephone that the leg was in excellent shape and that he was doing heavy work in the oil-trade, quite free from symptoms.

Scrutiny of this group of 14 patients establishes with certainty that a less than adequate functional and anatomical result was obtained in one patient: nr. 066, showing 3 cm shortening and 20° varus angulation. With regard to the remaining 13 patients it can only be stated that a good subjective result was obtained. It is improbable that this group of 14 patients involves a selection, and that the results of the follow-up study are influenced by the non-inclusion of these patients.

IX.4. PROCEDURE AT FOLLOW-UP

The procedure at follow-up was as follows. A history was taken, a physical and a radiological examination were made. All patients were examined by the same investigator: the author.

To begin with, the events of the accident were once again discussed with the patient. Treatment of the fracture and the hospital period were then discussed. The patient was questioned about incidents between discharge from hospital and the time of follow-up. He was then asked his opinion about the serviceability of the leg, and about symptoms, if any. Resumption of work, the work situation, and sports activities were then discussed.

The diagnostic physical examination started with a study of the patient's gait. The standing patient was then examined for a possible difference in leg length (i.e. a difference in the heights of the superior anterior iliac spines). The shape of the leg was examined with the patient recumbent. The strength of the peroneal musculature and the sensibility of the lower leg and foot were determined. The leg was palpated for pulsations of the posterior tibial artery and the dorsal artery of the foot. Next, the functions of the hip-joint, knee-joint and ankle-joint were measured and compared, if possible, with the corresponding contralateral functions. The circumference of the thigh was measured 15 cm above the medial intra-articular space. Finally, the presence or absence of crepitation in the femoropatellar joint was established.

The third and final part of the follow-up was radiological examination of the femur involved. The femoral shaft was photographed in two directions, in such a manner as to include hip-joint and knee-joint. Supplementary radiographs were obtained if there was a special reason to do so.

The entire follow-up examination took about 30 minutes. The vast majority of the patients took a very positive attitude towards the follow-up. It was appreciated that an interest in the patient's well-being was shown so many years after the accident. Only two of the total of 251 patients examined in the follow-up study asked for compensation of their travelling expenses.

IX.5. SUMMARY AND CONCLUSIONS

It has been pointed out in this chapter that personal examination is important in follow-up studies of affections of the suspensory and locomotor apparatus. An inquiry by letter gives insufficient information.

Mention is made of several possible methods of locating a patient.

Of the 329 patients with 335 femoral shaft

fractures, 265 were still alive at the time of the follow-up. Of these, 251 (i.e. 95%) could be personally examined at the out-patient clinic. The mean follow-up period was 4½ years after the accident, the range being from 2 years to 14½ years.

On the 14 patients not examined, information was obtained in writing or by telephone. It is improbable that this group constitutes a selection which has influenced the results of the follow-up study.

The follow-up consisted of a supplementary history, a physical examination and a radiological examination of the thigh involved.

IX.6. REFERENCES

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Chapter X
Anatomical and functional results

X.1. INTRODUCTION

This chapter discusses the anatomical and functional results obtained in the patients of the present series, and compares them with corresponding data from the literature. The various aspects, which are often interrelated, are discussed in separate sections.

The anatomical results are divided into differences in length, angular deformities and rotation deformities.

The functional results are discussed on the basis of the degree of mobility in the joints, particularly in the knee-joint.

As pointed out in Chapter IX, data were available on 251 patients followed up in the outpatient clinic. In 78 cases no follow-up was possible: because of intercurrent death in 64 cases, and for other reasons discussed in Chapter IX, in the remaining 14 cases.

X.2. DIFFERENCES IN LENGTH

In assessing differences in length of the lower limbs, minor physiological differences in length in a given individual are to be taken into account.

A difference in length after a femoral shaft fracture in an adult patient is as a rule a shortening due to fracture union with longitudinal dislocation. However, angular deformities can also contribute to shortening.

A difference in length can be established on the basis of clinical findings and by radiological examination.

There are several possibilities to establish a difference in length on the basis of clinical findings. Two methods were used in this study. Firstly: determination of a difference in height between the superior anterior iliac spines in the standing patient. The difference in length can be measured by placing boards of known thickness under the shortest limb. This method has an accuracy of $\pm$ 0,5 cm. This method cannot be used when other possible causes of a difference in length are involved, e.g. an abnormality of the lower leg.

A second clinical method is bilateral determination of the distance from the superior anterior iliac spine to the medial joint space of the knee. Differences in length arising from the lower leg are eliminated in this way, but such factors as hip abnormalities, etc., continue to exert an influence.

Exact determination of a difference in length can be achieved by radiological measuring. As a rule, however, this will not be done in a follow-up because there is no need for very exact determination of the difference in length, and also because the method is relatively cumbersome and exposes the patient to roentgen irradiation.

A myokinetic study by Morscher and Taillard (1965) revealed that patients with 1 cm leg shortening had an entirely normal locomotor pattern. Many patients with 2 cm shortening likewise show a normal gait and are free from symptoms. At shortening in excess of 2 cm, however, the pattern of walking is nearly always disturbed.

Nicod (1967) listed as late sequelae of leg shortening: talipes equinus, symptoms in the sacro-iliac joint, and compensatory scoliosis. This compensatory scoliosis can give rise to low back pain in the long run.

Differences in leg length are of importance in terms of insurance implications. Nicod (1967)

reported that the majority of German insurance companies grant 15% disability compensation at 4 cm shortening, and 30% at 6 cm shortening. At degrees of shortening of 3 cm or less, no compensation is as a rule granted.

Dencker (1963) reported that Swedish insurance companies grant 10–15% disability compensation for 4–6 cm shortening.

Dencker held that the number of instances of shortening after femoral shaft fractures diminished after introduction of Küntscher nail osteosynthesis. Böhler (1951) reported only 5 cases of shortening in 91 femoral shaft fractures treated by Küntscher nailing. Moeys (1952) observed only 7 cases of fracture union with shortening in 204 femoral shaft fractures treated by Küntscher nail osteosynthesis.

Dencker observed in his series that femoral shaft fractures treated by extension or cerclage united significantly more often with 1–2 cm shortening than fractures treated by Küntscher nailing or plate osteosynthesis. This difference did no longer apply at shortening of 3 cm or more. Shortening was as a rule due to complications: delayed union or non-union accounted for 75% of cases of 3–5 cm shortening, and infection for 25%. More than 5 cm shortening occurred in 11 cases in Dencker's series: 6 cases involved infection, 3 involved marked angulation, and 2 involved non-union.

In a follow-up study Blichert-Toft and Hammer (1970) found fracture union with 1–3 cm shortening in 5% of patients treated by Küntscher nailing, 18% of those treated by plate osteosynthesis, and 25% of those treated by extension.

Suiter and Bianco (1971), reporting on two selected groups of femoral shaft fractures, listed 6 cases of shortening in 31 conservatively treated patients, and only one case of shortening in 28 patients treated by Küntscher nail osteosynthesis without reaming of the medullary cavity.

In the present study, 41 patients were eliminated from the discussion of results in terms of differences in length, for reasons listed in table 73.

Table 73. Reasons for elimination from calculations concerning differences in length.

pre-existent difference in length	13
influenced by associated injury	10
amputation	3
influenced by accident during interval	5
remainder of 'unclassifiable' group	5
affected leg longer	5
Total	41

Table 73 shows that in five patients the fractured leg was longer than the intact leg. The difference was 1 cm in all cases. Three patients had been treated by Küntscher nail osteosynthesis, and two had received conservative treatment. Distraction may have been involved in one of the conservatively treated patients. None of the patients had noticed the difference in length, and none had pertinent symptoms.

The 210 remaining patients with valid observations on differences in length were divided into two groups:

* patients without shortening
* patients with shortening (1 cm or more).

Table 74 gives the numbers in the two groups and the distribution over the methods of treatment.

The incidence of differences in length proved to differ significantly in the different methods of treatment. In the conservatively treated groups, more than 50% of patients showed shortening; in the Küntscher nail osteosynthesis group this percentage was only 20, and in the plate osteosynthesis group it was less than 10.

In order to gain an impression of the degree of shortening, table 75 lists the number of centimetres of shortening for all patients with shortening.

Table 75 shows that the majority of patients had a shortening not exceeding 1–2 cm. In the groups 'K-nail with' and 'AO-plate' there were no fractures with more than 2 cm shortening.

Table 74. Shortening in relation to the various methods of treatment.

	Conservative	K-nail without	K-nail with	AO-plate
no shortening	25 47%	66 80%	33 79%	30 91%
shortening	28 53%	16 20%	9 21%	3 9%

$\chi_{(3)}^2 = 26.50$. Significant ($p < 0.001$)

Table 75. Degrees of shortening in relation to methods of treatment

Degree of shortening	Conservative	K-nail without	K-nail with	AO-plate
1 cm	10	7	8	2
2 cm	11	5	1	1
3 cm	5	2	–	–
4 cm	–	1	–	–
5 cm	2	–	–	–
6 cm	–	1	–	–

Of the total of 53 conservatively treated fractures followed up, seven (13.2%) united with 3 cm shortening or more. Of these seven fractures, six were comminuted while one was a spiral fracture with butterfly.

All patients with shortening were wearing a shoe with heel-and-sole elevation which corrected the difference in length. In one of the two patients with 5 cm shortening, a shortening osteotomy on the intact side has meanwhile been performed, after completion of the follow-up. The other patient with 5 cm shortening is working free from symptoms as a driver (prior to the accident, however, this patient had a physically more demanding job).

Shortening by 3 cm or more occurred in four of the 82 patients followed up after Küntscher nail osteosynthesis without reaming of the medullary cavity (i.e. 4.8%). In one patient, osteosynthesis of a comminuted fracture led to 4 cm shortening, partly because angulation resulted from premature weight-bearing. In spite of the shortening and in spite of a totally paretic arm due to the brachial plexus lesion sustained in the same accident, this patient fully resumed his work as an (independent) farmer. The shortening in the remaining three patients was due to a complication. In patient nr. 005, premature removal of the Küntscher nail was followed by a refracture, which united with shortening and angulation. In another patient the bone split during insertion of the Küntscher nail, whereupon the fracture united with shortening. In patient nr. 042, finally, 6 cm shortening remained; deep infection occurred in this patient, whose case history is presented in detail in Chapter VIII (page 75).

On the basis of the data from the literature and in view of the findings in the present series it can be maintained that operative fracture treatment as a rule results in no or nonimportant shortening of the limb. Conservative treatment, however, not infrequently results in shortening; this, however, is only slight as a rule. It may be possible to prevent shortening after conservative treatment by regularly comparing the distance between superior anterior iliac spine and medial joint space of the knee on the affected and on the intact side in patients which comminuted femoral shaft fractures treated conservatively. Control radiographs of the fracture as a rule give insufficient information on 'adequacy of length' of such a fracture.

X.3. ANGULAR DEFORMITIES

Angular deformities of the lower limb are not uncommon after either conservative or operative treatment (Müller 1967). Angular deformities after femoral shaft fractures are as a rule divided into deformities in the frontal plane (i.e. varus and valgus deformities) and deformities in the sagittal plane (i.e. antecurvation and recurvation). Rotation deformities, although essentially also angular deformities, will be discussed in a separate section for practical reasons.

With regard to angular deformities in the frontal and in the sagittal plane it is of importance to point out that the mechanical axis of the leg does not coincide with the anatomical axis of the femur.

The mechanical axis passes through the centre of the knee-joint. During walking the mechanical axis is displaced to the medial half of the knee-joint so that the knee is exposed to slight physiological varus stress. This is counteracted by, among other things, the iliotibial tract (Pauwels 1965).

In the case of angular deformity in the frontal plane (i.e. varus or valgus deformity), the mechanical axis is displaced in medial or in lateral direction, respectively. In the case of varus deformity this leads to overstretching of the lateral ligament. In addition, compression of the medial part of the tibial plateau and the medial femoral condyle results. Because the ligaments

gradually become overstretched, the joint always gapes a little during weight-bearing, and this intensifies the effect of the angular deformity (Debrunner et al. 1964). This unphysiological weight-bearing leads to degeneration of cartilage. Narrowing of the intra-articular space, sclerosis of the subchondral bone, osteophyte formation and cyst formation are radiological manifestations of this abnormal weight-bearing.

A similar train of events is conceivably involved in valgus stress, in which case the radiological manifestations of the arthrosis should first occur on the lateral side of the knee.

Severe antecurvation leads to genu flexum. In the sagittal plane the mechanical axis comes to be located behind the knee-joint. In that case the quadriceps muscles must be contracted during weight-bearing in order to prevent passive flexion of the knee. This causes compression in the femoropatellar joint.

In severe recurvation, the quadriceps muscles are relatively too long. In that case the required stability in the knee-joint during weight-bearing is achieved by hyperextending the knee. In the long run this leads to overstretching of the posterior articular capsule.

Few exact data on the late sequelae of angular deformities on weight-bearing joints can be found in the literature. This is probably due to the individual range of variation of the physiological skeletal axes. In view of this, a purely mathematical approach to angular deformities does not seem to be indicated (Ledermann 1967).

Nor are exact data available on the interval after which radiological changes can still occur. Debrunner (1967) indicated an interval of 5–30 years. Nicod (1967) believed that osteo-arthritis would not occur if no signs of it developed within the first five years.

It is generally agreed that varus deformity is a greater menace to the knee-joint than valgus deformity (Nicod 1967). Ramadier found osteo-arthritis in 57% of 60 cases of genu varum, and in only 38% of 99 cases of genu valgum.

It is difficult to formulate fixed rules concerning indications for corrective osteotomy. Numerous factors play a role in this respect, e.g. the patient's complaints, his age, his occupational activities, his mental attitude, and the presence or absence of osteo-arthritis. Nicod (1967) outlined two indications for corrective osteotomy in cases of varus deformity:

1. signs of incipient osteo-arthritis,
2. permanent displacement of the mechanical axis to the medial half of the knee-joint.

Nicod pointed out that an angular deformity has more unfavourable mechanical implications as the deformity is localized at a more distal level of the shaft.

Nicod recommended an expectant attitude towards valgus deformities, resorting to corrective osteotomy only if there are complaints. The indication for correction of recurvation or antecurvation also depends on the presence of complaints, according to Nicod. However, angulation exceeding 25° should be regarded as an indication for correction, in his view, even if there are as yet no complaints.

Clinical determination of angular deformities in the frontal and in the sagittal plane is difficult. These deformities are best diagnosed on the basis of radiographic examination in two directions. A particularly effective aid in diagnosis valgus and varus deformities is the so-called 'Ganz Aufnahme': an overall radiograph of the pelvis and lower limbs of the standing patient (Spirig 1967). This procedure, however, is too laborious for a follow-up, and entails a more serious exposure to irradiation than routine radiography!

Angular deformities in the patients of the present series were studied by means of two lateral and two anteroposterior radiographs of the femur which depicted the entire femur and the adjacent joints.

Dencker (1963) found no correlation between the direction of angulation and the symptoms. Consequently he brought varus deformity, valgus deformity, antecurvation and recurvation under a single heading: angular deformities. In 75% of his follow-up patients he found either no angulation or less than 10° angulation. Over 20° angulation was observed in 16 patients, i.e. 2%. These patients all had complaints, which Dencker did not specify; nor did he present radiological data on the joints.

Blichert-Toft and Hammer (1970) diagnosed angulation in 5 cases, all after conservative fracture treatment.

The present study discusses angular deformities (or rather: projections of angular deformities) in the frontal plane and in the sagittal plane. Angular deformities of less than 5° are left undiscussed.

Observations on 19 patients were eliminated as

of no validity, for reasons listed in table 76.

Table 76. Reasons for elimination from calculations concerning angular deformities.

amputation	3
accident during interval	5
X-ray examination omitted	1
remainder of 'unclassifiable' group	10
Total	19

There remained 232 observations.

VARUS AND VALGUS DEFORMITIES

The distribution of varus and valgus deformities over the various methods of treatment is shown in table 77.
The distribution of the incidence of angular deformities over the various methods of treatment shows a significant difference. Most angular deformities occurred after conservative treatment.

Table 78 gives an impression of the degree and of the direction of angular deformity.
Table 78 shows that angular deformities after conservative treatment were mostly varus deformities. This is undoubtedly due to the action of the adductor muscles.

Valgus deformities were more frequent after Küntscher nail osteosynthesis. AO-plate osteosynthesis was as a rule not followed by angular deformities in the frontal plane. The one patient with 5° varus deformity was patient nr. 329, in whom refracture occurred after a deep infection.

Table 78. Degree and direction of deformity varus or valgus in relation to methods of treatment.

	Conservative	K-nail without	K-nail with	AO-plate
varus				
5°	6	–	1	1
10°	5	2	1	–
15°	5	–	–	–
> 15°	1	3	–	–
valgus				
5°	6	10	3	–
10°	3	4	2	–
15°	–	–	2	–
> 15°	–	–	–	–

VARUS DEFORMITY

An analysis of the patients with 5–10° varus deformity shows that none of these patients had symptoms which could be traced back to the angular deformity. One patient had hip symptoms, which possibly resulted from a marked rotation deformity. This patient will be discussed in section X.4.

Of the 11 patients who had 5–10° varus deformity after conservative treatment, 8 had had a comminuted femoral shaft fracture. In one patient the fracture type was unknown, and in the remaining two there had been a transverse fracture with butterfly and a spiral fracture with butterfly, respectively.

Of the 9 patients with 15° varus deformity or more, 7 were entirely free from symptoms. One patient (nr. 249) with 15° varus deformity after refracture had vague low back pain and knee symptoms in follow-up. In this case a corrective osteotomy was performed after completion of the follow-up. Although virtually anatomical fracture union was achieved, the low back pain persisted and in addition the patient developed vague complaints about the thigh, which he ascribed to the operation.

Another patient with more than 15° varus deformity was nr. 042, who after a deep infection also showed 6 cm shortening. This patient had severe knee symptoms, but these were not exclusively due to the varus deformity.

The radiological data on the knee-joints of

Table 77. Frequency of varus or valgus deformity in relation to methods of treatment.

	Conservative	K-nail without	K-nail with	AO-plate
no varus or valgus	37 59%	68 78%	37 80%	35 97%
varus or valgus	26 41%	19 22%	9 20%	1 3%

$\chi_{(3)}^2 = 20.06$. Significant ($p < 0.001$).

patients with 15° varus deformity or more, are very interesting. In one case (patient nr. 054) interpretation of the radiograph of the knee-joint was difficult because this patient also sustained a knee injury in the accident. One patient (nr. 042) showed narrowing of the intra-articular space, but in addition to 15° varus deformity she showed 6 cm shortening and antecurvation. None of the remaining seven patients showed any radiological evidence of osteo-arthritis. The period of observation ranged from 2 to 11 years.

In the present series, therefore, there is in fact no evidence that on the short-term a varus deformity is a menace to the knee-joint. A conclusion on the long-term effect cannot be presented on the basis of this material.

VALGUS DEFORMITY

An analysis of the patients with 5–10° valgus deformity shows that these patients were generally free from symptoms. Of the 14 patients treated by Küntscher nail osteosynthesis 'without' (table 78), 7 had a fracture immediately below the isthmus. The cause of the valgus deformity in these cases was probably an insufficient hold of the Küntscher nail in the distal fragment in fractures of this type.

Of the 9 fractures given conservative treatment, 5 were comminuted fractures and 4 were transverse fractures, with or without butterfly.

All except one of the 7 patients who developed a valgus deformity after Küntscher nail osteosynthesis had no complaints about the leg. In five cases there was a rotation deformity as well as a valgus deformity. One of these patients (nr. 330) had 10° valgus deformity and 20° endorotation. He was unable to continue his work as a postman because of fatigue in the entire leg, and was transferred to a drawing-office where he has worked free from symptoms.

The two patients with 15° valgus deformity were young patients, entirely free from symptoms. There was no radiological evidence of osteo-arthritis of the knee-joint. However, in both cases the period of observation has been short.

ANTECURVATION AND RECURVATION DEFORMITIES

Table 79 shows the incidence and distribution of antecurvation and recurvation over the various methods of treatment.

Table 80 shows the degree and direction of antecurvation and recurvation in relation to the various methods of treatment.

Table 80 shows that most of these angular deformities were recurvations. In patients treated by Küntscher nail osteosynthesis, the physiological antecurvation of the femoral shaft is abolished by the straight nail. This explains the large number of patients with slight recurvation in the Küntscher nail osteosynthesis groups. The two patients who showed 5° recurvation after A.O.-plate osteosynthesis were patients with a refracture (nrs. 322 and 329). Patient nr. 329 had a refracture following a deep infection.

Table 79. Frequency of antecurvation or recurvation in relation to methods of treatment

	Conservative	K-nail without	K-nail with	AO-plate
no antecurv. or recurv.	38 60%	52 60%	34 74%	34 94%
antecurv. or recurv.	25 40%	35 40%	12 26%	2 6%

$\chi_{(3)}^2 = 16.75$. Significant ($p < 0.001$)

Table 80. Degree and direction (antecurvation or recurvation) of deformity in relation to methods of treatment.

		Conservative	K-nail without	K-nail with	AO-plate
antecurvation	5°	1	–	–	–
	10°	–	1	–	–
	15°	2	1	–	–
	> 15°	2	3	–	–
recurvation	5°	14	26	11	2
	10°	5	4	1	–
	15°	–	–	–	–
	> 15°	1	–	–	–

RECURVATION

None of the patients with recurvation were inconvenienced by the angular deformity. Genu recurvatum did not occur. The only conservatively treated patient with more than 15° recurvation had sustained a highly comminuted femoral shaft fracture, which united with 20° recurvation. This did not inconvenience the patient, who even participated intensively in sport. There was 20° limitation of knee flexion. Radiological examination of the knee-joint 30 months after the accident revealed no evidence of osteo-arthritis.

ANTECURVATION

Antecurvation was not often observed, and only after conservative treatment and in a few cases after Küntscher nailing. Patients with 5–10° antecurvation showed no symptoms as a result of this deformity. The four conservatively treated patients with 15° antecurvation or more were likewise all free from symptoms. All recovered full extension. There was no radiological evidence of osteo-arthritis of the knee-joint.

The four patients with 15° antecurvation or more after Küntscher nail osteosynthesis, had all developed a complication during treatment. Refracture occurred in two (nrs. 005 and 094), deep infection developed in one (nr. 042) and in the fourth patient weight-bearing was started too early, after which angulation occurred. Two of these patients had complaints about the knee joint (nrs. 005 and 042). Interpretation of the radiographic features of the knee in these cases was impeded by their conditions (one had had a patellectomy and one had had a deep infection followed by varus deformity and 6 cm shortening).

Plate osteosynthesis proved to be a highly suitable means of fixation and maintenance of anatomical reduction. Only after a complication was there a risk of angulation, which as a rule remained limited.

Küntscher nail osteosynthesis with reaming of the medullary cavity likewise generally gave adequate maintenance of reduction. It seemed of no importance that the physiological antecurvation of the femur was often abolished by the Küntscher nail. Slight valgus deformity occurred in a few cases after Küntscher nail osteosynthesis, but as a rule proved not to inconvenience the patients.

Küntscher nail osteosynthesis without reaming of the medullary cavity also ensured fair maintenance of reduction, but if a complication occurred it could nevertheless be followed by considerable angular deformity.

Conservative treatment offers no complete guarantee for anatomical restoration of the femoral shaft. An angular deformity was found in 40% of the patients followed up in this study. Not infrequently they were patients with a comminuted fracture. It can be imagined that precisely these fractures pose problems in achieving and maintaining alignment.

The present series includes a few instances of fracture union in considerable varus deformity. But the unfavourable effect of this deformity on the knee-joint which is mentioned in the literature, was not observed in the patients of the present series. In this respect it is to be noted that the period of observation in these cases was rather short for evaluation of any such effect.

X.4. ROTATION DEFORMITIES

Little is known about the incidence and effects of rotation deformities after femoral shaft fractures. One of the reasons for this may be sought in the fact that a rotation deformity cannot be established on routine X-ray (Nicod 1967) and therefore is not identified as such.

The hip-joint and the lumbar spinal column afford substantial possibilities for correction of rotation deformities. Nicod (1967) held that unmistakable clinical symptoms occur at rotation deformities exceeding 20°: in the case of exorotation the patient brings the compensating hip forwards, whereas in the case of endorotation this hip is brought back. Nicod believed that a rotation deformity is a menace, not so much to the hip-joint as to the knee-joint. In the case of exorotation osteo-arthritis is believed to occur on the lateral side of the knee, while endorotation is believed to give rise to osteo-arthritis on the medial side of the knee. Compensation in the

lumbar spinal column can give rise to low back pain.

Müller (1967) believed that a rotation deformity of the femur can give rise also to symptoms in the metatarsals and in the ankle-joint.

Rehn et al. (1968) and Leitz (1968) advised preventive corrective osteotomy in the case of a rotation deformity of the femoral shaft.

Van Joost and Gastkemper (1972) were unable to formulate fixed rules covering the indication for a corrective osteotomy in cases of rotation deformity of the femoral shaft. They allowed the symptoms to determine the indication, but held that a corrective operation is as a rule indicated at any rotation deformity exceeding 25°.

Sommerville (1963) expressed the opinion that, in the long run, rotation deformities have more unfavourable effects than deformities in the frontal and the sagittal plane.

Dencker (1963) measured the rotation deformity in his patients by inspection of the limb, thus establishing in some 10% of his patients a rotation deformity not exceeding 20°, and always involving exorotation; he observed no case of endorotation. It seems probable that this method of establishing rotation deformities by inspection, is insufficient.

Blichert-Toft and Hammer (1970) reported having found a rotation deformity in 5 out of 37 patients treated by Küntscher nail osteosynthesis, 1 out of 11 treated by plate osteosynthesis, and 1 out of 28 treated conservatively. Rokkanen et al. (1969) reported that 10% of their patients showed a rotation deformitiy of more than 10° after Küntscher nail osteosynthesis. In a group of conservatively treated patients examined for comparison this percentage was 4.

Rotation deformities can be adequately diagnosed on the basis of clinical findings. Radiological methods to this effect have been described by Dunn (1952) and Ripstein (1955). They compared increased or diminished anteversion on the affected side with the anteversion on the intact side. This procedure, however, exposes the patient to considerable irradiation.

In the present study rotation deformity was determined in the recumbent patient, with the hip-joint and the knee-joint both in 90° flexion. The knee was fixed with one hand, while the other hand was used to rotate the lower leg, so that passive rotatory movements are executed in the hip-joint. The excursions were measured. Whenever possible, a comparison was made with the intact side.

No valid information was available on 45 of the follow-up patients. The reasons for their elimination are listed in table 81.

Table 81. Reasons for elimination from calculations concerning rotation deformities.

pre-existent abnormalities	11
influenced by associated injuries	11
accident during interval	9
amputation	3
contracture and paraplegia	2
remainder of 'unclassifiable' groups	9
Total	45

The principal reason for eliminating the observations on a fairly large group of patients lay in the fact that rotation was always compared with that on the intact side. All patients with a pre-existent or posttraumatic rotation deformity on that side were therefore excluded from the calculations. The remaining 206 observations were divided into two groups:

* no rotation deformity
* rotation deformity (10° or more).

The distribution of these two groups over the various methods of treatment is shown in table 82.

The presence of a rotation deformity shows a significant difference in distribution over the methods of treatment. Küntscher nail osteosynthesis proved to be associated with a rotation

Table 82. Frequency of rotation deformities in relation to methods of treatment.

	Conservative	K-nail without	K-nail with	AO-plate
no rotation deformity	32 63%	38 51%	24 52%	30 88%
rotation deformity	19 37%	37 49%	22 48%	4 12%

$\chi^2_{(3)} = 15.39$. Significant ($p < 0.01$).

deformity in about 50% of cases. Again, A.O.-plate osteosynthesis compares very favourably, with slightly over 10%.

Table 83 gives an impression of the degree and direction of the rotation deformity.

Table 83. Degree and direction (exorotation or endorotation) of rotation deformity in relation to methods of treatment. Figures in brackets in the K-nail columns indicate the number of closed procedures.

	Conservative	K-nail without	K-nail with	AO-plate
exorotation				
10°	3	10 (1)	4 (2)	2
20°	6	12 (0)	6 (4)	1
30°	2	5 (0)	6 (4)	–
40°	–	1 (0)	1 (1)	–
50°	–	1 (0)	–	–
endorotation				
10°	6	6 (0)	3 (2)	1
20°	2	–	3 (2)	–
30°	–	1 (0)	–	–
40°	–	–	–	–
50°	–	–	–	–

Rotation deformities were as a rule limited to 10–20° in patients treated with an A.O.-plate and those given conservative treatment. The majority of the rotation deformities after Küntscher nail osteosynthesis were likewise in this range, but in this group there were a few patients with 30° and some with even 40–50° rotation deformity.

Comparison with Rokkanen's study in which 10% of patients had rotation deformities of more than 10°, shows that by the same criteria this percentage in the present series was 26.6 after Küntscher nail osteosynthesis without, and 34.8 after Küntscher nail osteosynthesis with reaming of the medullary cavity.

The rotation deformity was as a rule exorotation. In the patients with Küntscher nail osteosynthesis without reaming of the medullary cavity, the rotation deformity probably developed in the postoperative period. With this technique of osteosynthesis rotation is not sufficiently precluded, and consequently the distal fragment rotates outwards in response to the effect of the force of gravity on the foot.

Küntscher nail osteosynthesis with reaming of the medullary cavity usually does preclude rotation. Rotation deformities in these patients possibly resulted from the fact that a closed procedure of osteosynthesis was used. Rotation cannot be properly assessed by means of the image intensifier; and the usual lateral recumbent position of the patient on the extension table likewise facilitates development of a rotation deformity (Koslowski and Weller 1962, Weber 1967).

The literature also mentions serious rotation deformities after this type of osteosynthesis. Gillquist et al. (1971), discussing 19 femoral shaft fractures treated by this technique, reported one patient with a rotation deformity of sufficient severity to necessitate subsequent corrective osteotomy.

Rascher et al. (1972) reported one instance of 45° exorotation in 30 femoral shaft fractures treated in this manner. In this patient the Küntscher nail was withdrawn to a level cranial to the fracture two weeks after the osteosynthesis, whereupon the exorotation was corrected and the nail driven in again.

An analysis was made of all patients in the present series with a rotation deformity of 20° or more.

EXOROTATION

Twenty-five patients showed 20° exorotation. In two of these patients there were multiple deformities, e.g. antecurvation and varus deformity in patient nr. 005, as a result of refracture, and marked limitation of knee function due to rupture of a quadriceps tendon in patient nr. 245. Both patients had knee symptoms, but are not included in this analysis. Of the remaining 23 patients, 8 showed symptoms: 4 complained of a stiff knee after much walking; 2 complained of fatigue in the leg after any exertion exceeding average use; the remaining 2 complained of a tired feeling in the hip.

In none of these cases did examination of the radiographs reveal any change in the hip or the knee-joint which indicated osteo-arthritis.

Thirteen patients showed 30° exorotation. One of these was patient nr. 218, who had sustained a lesion of the superficial femoral artery and the sciatic nerve (see Chapter XII). This patient was excluded from the analysis. The remaining 12 patients included 6 with complaints about the limb. One patient was inconvenienced only when playing football; he also complained that he

could not skate well because of the exorotation of the foot. The remaining 5 patients complained of fatigability of the leg upon exertion. In none of these 13 patients did radiological examination of the hip-joint and knee-joint reveal any evidence of osteo-arthritis of one of these joints.

In two patients the fracture had united in 40° exorotation. One patient was entirely free from symptoms, in spite of intensive activities in boxing. Radiological examination revealed no evidence of osteo-arthritis either of the hip-joint or of the knee-joint.

The other patient was nr. 243, who was doing heavy manual work as a gardener. After a day's work he had vague symptoms of pain in the hip, which was tired and felt stiff. On the basis of the rotation deformity this patient received 45% disability compensation. He refused the offer of a corrective osteotomy: he considered his symptoms to be too slight to warrant this, and was afraid of losing his compensation. Radiological examination of the hip and the knee of this patient revealed no evidence of osteo-arthritis.

The one patient with 50° exorotation was receiving 30% disability compensation. He had considerable complaints about the knee-joint: fatigability and spontaneous pain; stiffness in the morning. Radiological examination 8 years after the accident revealed no evidence of osteo-arthritis in the hip-joint, but the knee-joint showed unmistakable features of osteo-arthritis. The radiograph is presented in fig. 33. A corrective osteotomy was repeatedly suggested to this patient, but in spite of his undoubtedly serious complaints he refused.

ENDOROTATION

There were five patients with 20° endorotation, one of whom had vague symptoms. This patient also showed a valgus deformity, and he complained of a sensation of fatigue in the leg. He was unable to continue his work as a postman. After being transferred to a drawing-office, he was free from symptoms. In none of these patients did radiological examination of the hip-joint and knee-joint reveal any evidence of osteo-arthritis of these joints.

One patient showed 30° endorotation. Apart from slight limitation of knee function, this patient was free from symptoms. Radiological examination of the hip-joint and knee-joint disclosed no evidence of osteo-arthritis.

The literature comprises few communications on the occurrence of rotation deformities after femoral shaft fractures. In the present series, however, this deformity was frequently seen. For example, 50% of patients treated by Küntscher nail osteosynthesis developed a rotation deformity, usually exorotation. Patients with 30% exorotation or more can consequently develop symptoms of the hip, the entire leg or the knee. Radiological changes were found in only one patient, with 50° exorotation. Contrary to Nicod's view (1967), the patient with osteo-arthritis showed the changes mainly on the medial side and not on the lateral side of the knee-joint.

There are two possible causes of the large percentage of rotation deformities after Küntscher nail osteosynthesis.

1. Küntscher nail osteosynthesis without reaming of the medullary cavity usually ensures insufficient fixation with regard to rotation. Under the influence of the force of gravity the foot rotates outwards, and the distal fracture fragment follows this exorotation.
2. Küntscher nail osteosynthesis with reaming of the medullary cavity was usually done as a closed procedure, and the position of the patient on the extension table might be one of the factors which impede assessment of rotation.

The latter method of osteosynthesis as a rule ensures adequate fixation as to rotation, and the rotation deformity in these patients can therefore be assumed to have occurred during the operation.

Rotation deformities are rarely observed after A.O.-plate osteosynthesis, probably because in this procedure the bone is exposed over a considerable distance, so that rotation can be accurately assessed; moreover, plate osteosynthesis as such ensures good fixation of the fracture.

X.5. KNEE FUNCTION

Recovery of the function of the knee-joint is one of the most important aspects of the treatment of femoral shaft fractures. Yet the available literature on this subject is rather scanty.

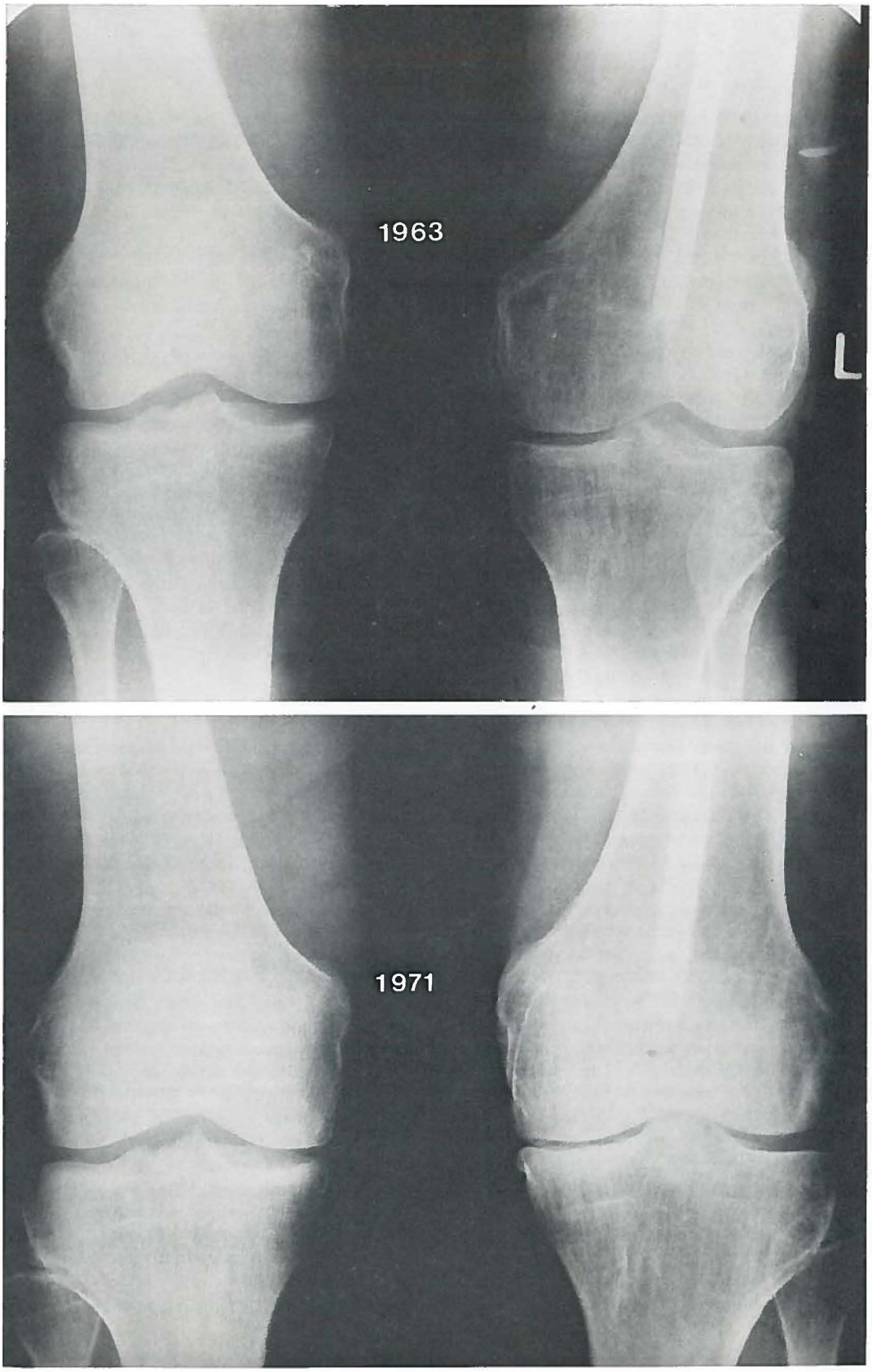

Figure 33. Radiographs of the knee-joint of the patient with 50° exorotation.
The uppermost radiograph shows the situation shortly after osteosynthesis of the femoral shaft fracture on the left. The lowermost shows both joints eight years later. At the medial side of the left knee narrowing of the articular joint with sclerosis of the subchondral bone is present.

Charnley (1947) maintained that the key to an excellent recovery of knee-joint function will be found as soon as the key to rapid fracture union is found. He held that intra-articular adhesions as a result of immobilization are only of subordinate importance. It is the adhesions in the quadriceps muscles that really matter.

Watson-Jones (1955) confirmed Charnley's views. After rapid fracture union there is hardly ever any permanent stiffness of the knee-joint. In fact this really occurs only after delayed union. Watson-Jones distinguished three causes.

1. Formation of adhesions around the knee-joint during immobilization. It is of importance according to Watson-Jones to immobilize the knee in slight flexion, and to start active exercises with the quadriceps muscles immediately.
2. Stiffness of the knee-joint due to fixation of the patella. This is believed to occur in particular in the case of patellar fractures.
3. Fixation of the quadriceps muscles to the femoral shaft in the vicinity of the fracture.

Watson-Jones, too, regards the lastmentioned cause as the most common and most important.

In 1968 Charnley again pointed out that in his opinion recovery of knee function depended on the ability of the organism to absorb and remove the temporary repair tissue around the fracture.

A number of clinical series are available for comparison with the data on the present series. Nichols (1963) examined patients with femoral shaft fractures in a military rehabilitation centre. Two-thirds of these patients recovered a degree of mobility of 90° flexion or more. There was a difference in degree of mobility between comminuted and 'simple' fractures, regardless of the method of treatment used. Of the patients with comminuted fractures, only 58% recovered a degree of mobility of 90° or more; in the group with 'simple' fractures this percentage was 78.

Nichols established a relationship between the duration of fracture union and the percentage of patients with full recovery of knee function.

Dencker (1963) found a knee function of less than 90° flexion in 12% of his patients with closed femoral shaft fractures. In patients with open fractures this percentage was 27. An enumeration of causes indicated that the cause was either a disturbance of union or infection of the femoral shaft fracture. On the basis of his large material, Dencker concluded that traction through the tibial tuberosity cannot as such give rise to limitation of knee function or an unstable knee.

Dencker observed an extension defect in only 1% of cases. Limitation of hip function and ankle function was observed in only very few cases. Most of these involved failure of treatment, e.g. purulent arthritis following deep infection of the femoral shaft fracture.

In the present series the intention was to measure recovery of knee function from two parameters:

1. restoration of the volume of the quadriceps muscles;
2. the degree of mobility in the knee-joint.

In all patients the circumference of the affected and the intact thigh was measured 15 cm above the medial joint space of the knee. Widely varied differences between the affected and the intact thigh were observed. In a number of cases the thigh circumference on the affected side exceeded that on the intact side. It was found that many different factors determine the thigh circumference. They included:

* individual variations in the volume of the quadriceps muscles;
* shortening;
* associated injuries;
* callus volume.

In a relatively large number of patients, moreover, the intact side could not be used as reference because of pre-existent or posttraumatic changes. After due consideration it was finally decided that this study should not give conclusions based on a difference in thigh circumference between the affected and the intact side.

The same decision had to be made with regard to the observations on femoropatellar crepitation. All patients were examined for crepitation upon movement of the knee-joint on the affected and on the intact side. But again so many factors were found to interfere with observations that no calculations and conclusions seemed warranted.

With regard to the degree of mobility in the knee-joint, observations on 42 patients had to be eliminated, for reasons listed in table 84.

There remained 209 observations, which were divided into two groups:

a. patients without limitation of movement;
b. patients with limitation of movement (10° or more).

Table 85 presents the relevant data and the distribution over the various methods of treatment. A significant difference proved to exist in the dis-

Table 84. Reasons for elimination from calculations concerning limitation of movement.

pre-existent abnormalities knee affected leg	5
pre-existent abnormalities contralateral knee	4
accident during interval	6
associated knee injury	14
paraplegia	1
amputation	3
remainder of 'unclassifiable' group	9
Total	42

tribution of the groups of patients with and without limitation of movement over the various methods of treatment.

Limitation of movement remained in particular after conservative treatment. Few patients showed limitation of movement after Küntscher nail osteosynthesis with reaming of the medullary cavity or after A.O.-plate osteosynthesis. An analysis of the patients with limitation of movement is given in table 86.

Table 86. Degree of limitation of movement in relation to methods of treatment.

limitation	Conservative	K-nail without	K-nail with	AO-plate
10°	11	8	2	2
20°	10	1	2	–
30°	4	3	–	2
40°	4	–	–	–
50°	–	2	–	–
60°		4	–	–
70°	–	–	–	–
> 70°	–	1	–	–

Table 86 shows that limitation of movement in the conservatively treated patient was usually between 10° and 20°, although some patients showed 30–40° limitation of movement. This means that in this group there are in fact no patients with less than 90° knee flexion. In the groups 'K-nail with' and 'AO-plate' the number of patients with limitation of movement was small and the degree of limitation was only slight.

The two patients with 30° limitation of movement after A.O.-plate osteosynthesis were both patients in whom deep infection had occurred. That the limitation did not exceed 30° is undoubtedly due to the fact that, despite the deep infection, the osteosynthesis material ensured sufficient stability for recovery of function in the limb.

Patients with less than 90° knee flexion were to be found in the group 'K-nail without'. They were seven out of a total of 80 patients, i.e. 8.7%. This percentage is smaller than that in Dencker's series.

An analysis of causes showed that the two patients with 50° limitation of movement both had associated homolateral injuries (one patient a femoral neck fracture and a lower leg fracture, and the other patient a small patellar fracture). In the latter patient the femoral shaft fracture united with recurvation. The first patient was, the second patient was not inconvenienced by the limitation of movement.

The four patients with 60° limitation of movement were not seriously inconvenienced by it. Lysis of the quadriceps muscles was effected twice in one patient, without the desired effect. The radiograph showed callus on the anterior aspect of the femoral shaft in this patient, in whom there were probably very pronounced adhesions between femoral shaft and quadriceps muscles.

In another patient of this group, gauze was left behind in the osteosynthesis operation, and later removed via a medial approach. It is possible that cicatricial tissue produced by this intervention caused the limitation of movement in this case. In the two remaining patients with 60° limitation of movement, no distinct cause could be determined.

The one patient with > 70° limitation of move-

Table 85. Frequency of limitation of movement in relation to methods of treatment.

	Conservative	K-nail without	K-nail with	AO-plate
no limit. of movement	26 47%	61 76%	39 91%	27 87%
limit. of movement	29 53%	19 24%	4 9%	4 13%

$\chi_{(3)}^2 = 28.99$. Significant ($p < 0.001$).

Table 87. Frequency of limitation of movement in relation to fracture types.

	Bending		Comminuted		Torque	
no limitation of movement	128	80%	21	47%	7	70%
limitation of movement	32	20%	24	53%	3	30%

$\chi_{(2)}^2 = 19.63$. Significant ($p < 0.01$).

ment had a virtually ankylotic knee-joint after a deep infection.

The possible importance of the fracture type in the groups with and without limitation of movement in the knee-joint was also examined. It is to be borne in mind in this respect that considerable differences in composition existed between the two groups. Table 87 presents the relevant data and the distribution over fracture types.
Table 87 shows a significant difference in distribution. Limitation of movement was most common in the case of comminuted fractures. The soft-tissue injuries in these fractures are likely to be more severe than those in bending and torque fractures. These soft-tissue lesions heal with cicatrization, and this connective tissue at least partly explains the limitation of movement.

An extension defect was established in 11 of the follow-up patients. There were several responsible factors: quadriceps rupture, quadriceps adhesions, sequela of cerebral contusion, refracture, deep infection and associated knee injury. As a rule these patients were inconvenienced by the limitation of movement.

Finally, efforts were made to establish whether any patients had limitations of movement in the hip-joint or ankle-joint as a result of the femoral shaft fracture. No patients with disturbed hip function (in relation to the femoral shaft fracture) were found, apart from the patients with rotation deformities. Complaints about the hip-joint were rare, but ten patients mentioned severe symptoms at the site of the point of the Küntscher nail, which disappeared after removal of the nail. A study of the radiographs of these patients showed that in all these cases the Küntscher nail protruded from the trochanter by a few centimetres.

Rokkanen et al. (1969) also reported complaints about the site of the point of the nail in a number of patients treated by Küntscher nail osteosynthesis. It seems advisable, therefore, to insert the Küntscher nail down to the level of the greater trochanter.

Permanent limitation of function in the ankle-joint as a result of femoral shaft fracture treatment occurred in one patient, who developed talipes equinus during and after conservative treatment. Elongation of the Achilles tendon was effected 7 months after the accident. At follow-up 6 years after the accident 10° limitation of dorsoflexion was found.

X.6. SUMMARY AND CONCLUSIONS

This chapter discusses the anatomical and functional results found at follow-up on 251 patients in the present series. Whenever possible, these results are compared with those reported in the literature.

The anatomical results were evaluated on the basis of a difference in length, angular deformity in the frontal and in the sagittal plane, and rotation deformity.

The functional results were assessed on the basis of the degree of mobility in the knee-joint.

The presence of a difference in length shows a significant difference in distribution over the methods of treatment. Some 50% of conservatively treated patients showed shortening. The rate of occurrence of shortening in patients treated by Küntscher nail osteosynthesis was about 20%. Shortening was rare in patients treated by A.O.-plate osteosynthesis.

An analysis of the patients with shortening showed that the degree of shortening after Küntscher nail osteosynthesis with reaming of the medullary cavity and after A.O.-plate osteosynthesis did not exceed 2 cm. With the other two

methods the shortening also remained limited to 2 cm in the majority of patients. The patients in the present study did not experience 2 cm shortening as an inconvenience. This observation confirms the data in the literature.

In a few patients shortening exceeded 2 cm. After Küntscher nail osteosynthesis without reaming of the medullary cavity it was usually the complications which led to this shortening. The conservatively treated patients mostly had comminuted fractures. During conservative treatment of fractures of this type it is difficult to establish on the basis of radiographs whether full length is attained; it is therefore proposed that frequent clinical determinations of length be included in the conservative treatment of comminuted fractures.

Angular deformities in the frontal plane (varus and valgus deformities) were most frequent after conservative treatment: 41% of the follow-up patients. These deformities were much less common in operatively treated patients. Angular deformities in the frontal plane showed a significant difference in distribution over the various methods of treatment. In the 'AO-plate' group there was only one patient with an angular deformity: slight varus deformity in a patient in whom deep infection had occurred.

Valgus deformities in the order of 5–10° were observed after conservative treatment and Küntscher nail osteosynthesis. They proved not to cause clinical symptoms or radiological abnormalities of the hip-joint or knee-joint.

The angular deformity after conservative treatment was usually a varus deformity. This is probably due to the role played by the adductor muscles. Six patients showed 15° varus deformity or more. The group 'K-nail without' included three patients with 15° varus deformity or more. None of these nine patients with 15° varusdeformity or more really had serious complaints about the knee-joint in connection with the varus deformity, nor did they show any indications of osteoarthritis of the hip-joint or knee-joint. The literature suggests that valgus and particularly varus deformities are a menace to the knee-joint. The data obtained in the present series do not confirm this suggestion. It is to be noted, however, that the interval between accident and follow-up may have been too short to warrant conclusions in this respect.

Angular deformities in the sagittal plane (antecurvation and recurvation) showed a significant difference in distribution over the methods of treatment. Antecurvation or recurvation was rarely observed after A.O.-plate osteosynthesis, and only in connection with a complication. After Küntscher nail osteosynthesis the angular deformity was usually slight recurvation, based on the fact that a Küntscher nail sometimes neutralizes the physiological antecurvation of the femur.

A few instances of 15° antecurvation or more after Küntscher nail osteosynthesis without reaming of the medullary cavity can be traced back to complications such as refracture or deep infection.

Of the conservatively treated patients, 40% showed antecurvation or recurvation (usually 5–10° recurvation). A few patients with 15° antecurvation or recurvation or more were not inconvenienced by the deformity. No radiological evidence of osteo-arthritis in the femorotibial joint was found.

The present series showed a remarkably high rate of rotation deformities as compared with the literature. In this respect, too, there was a significant difference in distribution over the various methods of treatment. Again, A.O.-plate osteosynthesis compared favourably: only 12% rotation deformities, always only slight. After conservative treatment rotation deformities were observed in 37% of cases, usually 10–20°. After Küntscher nail osteosynthesis, without or with reaming of the medullary cavity, a rotation deformity occurred in nearly 50% of cases. The deformity was more often exorotation than endorotation. A few patients showed 40° and 50° exorotation!

Two possible explanations are mentioned for this large number of rotation deformities after Küntscher nail osteosynthesis.

1. After Küntscher nail osteosynthesis without reaming of the medullary cavity, rotation in the fracture is insufficiently controlled. In the postoperative phase the foot turns in exorotation, and the distal fracture fragment rotates with it.
2. After Küntscher nail osteosynthesis with reaming of the medullary cavity, rotation is as a rule under control. In these cases the rotation deformity probably occurs during the operation. Due to the lateral recumbent position of the patient on the extension table the exact position of the peripheral fragment cannot be

assessed, and the radiological features give insufficient information on rotation.

Patients with 20° exorotation or more can be inconvenienced by it in that the leg and knee, and sometimes also the hip, tire easily upon exertion. Radiological evidence of osteo-arthritis of the knee-joint or hip-joint was not observed in patients with 20°, 30° and 40° exorotation. The one patient with 50° exorotation did show unmistakable degenerative changes in the knee-joint. This patient also had marked clinical symptoms.

Endorotation, as pointed out, was less frequently observed. This, too, can give rise to complaints. The findings in the present series do not confirm the suggestion in the literature that endorotation more readily and more frequently gives rise to clinical symptoms.

Functional results were assessed on the basis of recovery of knee function. No use was made of data on the difference in circumference between affected and intact thigh (the so-called quadriceps atrophy), because there are too many factors which influence a comparison.

The groups of patients with and without limitation of movement in the knee showed a significant difference in distribution over the various methods of treatment.

In the stable osteosyntheses (e.g. Küntscher nail osteosynthesis with reaming of the medullary cavity and A.O.-plate osteosynthesis) there were few instances of limitation of movement in the knee, and the degree of limitation did not exceed 30°. These patients, moreover, had had a deep infection.

After Küntscher nail osteosynthesis without reaming of the medullary cavity, about one out of four patients examined showed limitation of movement. In the majority of cases the degree of limitation was 10–30°, but a few patients showed 50° and 60° limitation of movement. One patient had a virtually ankylotic knee-joint; this patient had had a deep infection.

Limitation of movement was most frequently seen after conservative treatment. More than 50% of patients in this group had limitation of movement, but in the majority of cases this was only 10–20°. In no case did more than 40° limitation of movement occur after conservative treatment.

Finally, efforts were made to establish whether presence or absence of limitation of movement in the knee-joint could be related to fracture type. Some reservations must be made because the groups showed considerable differences in composition (as pointed out in Chapter IV).

Patients with and without limitation of movement showed a significant difference in distribution over the fracture types. The frequency of limitation of movement was 20% in bending fractures and 30% in torque fractures. That in comminuted fractures was 53%. It seems probable that in comminuted fractures the soft-tissue injury as a rule exceeds that in bending or torque fractures, and that consequently the risk of connective tissue formation and adhesions is greater. This is confirmed by the findings of Charnley (1947), showing that it is in particular the adhesions between the quadriceps muscles and between these muscles and the femoral shaft that give rise to permanent limitation of movement in the knee-joint.

In the present series, disturbances in the function of the hip-joint as a result of the femoral shaft fracture were not observed except in patients with rotation deformities. Pain in the region of the hip was indicated by patients in whom a Küntscher nail protruded too far from the trochanter. These complaints ceased after removal of the nail.

One patient showed limitation of movement in the ankle-joint. After conservative treatment of a femoral shaft fracture this patient developed talipes equinus, for which an elongation of the Achilles tendon was effected. The follow-up revealed 10° limitation of dorsoflexion.

Conservative treatment did not in all cases lead to complete anatomical and functional restoration of the femoral shaft. The rate of disturbances in either anatomical or functional restoration ranged from 40 to 50%. A.O.-plate osteosynthesis, however, virtually guaranteed full anatomical and functional recovery. In the few cases in which this was not achieved, there had been complications.

Of the Küntscher nail osteosyntheses, that with reaming of the medullary cavity compares favourably with the Küntscher nail without reaming. However, the fine results of Küntscher nail osteosynthesis with reaming of the medullary cavity are marred by the high rate of rotation deformities.

After Küntscher nail osteosynthesis without reaming there are usually fewer differences in

length, angular deformities and limitations of movement in the knee-joint than after conservative treatment. But an analysis shows that the degree of difference, deformity or limitation was not infrequently rather considerable. This was nearly always due to a complication.

That angular deformities in the frontal and sagittal plane are a menace to the knee-joint, as the literature indicates, could not be confirmed on the basis of the findings in the present series. However, the interval between accident and follow-up may have been too short to warrant definite conclusions.

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Chapter XI
Socio-economic aspects

XI.1. INTRODUCTION

This chapter will discuss some socio-economic aspects of femoral shaft fractures. The available literature on this subject is relatively scanty. Some data from the literature will be discussed before the findings in the present series are described. The aspects considered are duration of hospital period, duration of unfitness to work, and change of occupation. Each will be discussed in relation to the metod of treatment. It is to be borne in mind in this respect that many factors not directly related to the fracture treatment, exert an influence. For example, the duration of the hospital period for a patient with a femoral shaft fracture partly depends also on pre-existent diesase, associated injuries, availability of facilities for adequate care at home, etc.

A change of occupation and the duration of unfitness to work are influenced by the type of work, the labour situation in general, the patient's age, recovery from associated injuries and the patient's personality structure.

It is to be expected that the period a patient with a femoral shaft fracture must spend in hospital can be substantially shortened by operative treatment of the fracture, particularly if the osteosynthesis is so stable that supplementary immobilization of the fracture is superfluous. On the other hand, such complications as a deep infection can entirely cancel out the favourable effect of operative treatment.

Whether or not the fracture is operatively treated cannot be expected to exert a marked influence on the duration of unfitness to work. As a rule, after all, patients with a femoral shaft fracture are unlikely to resume work until fracture union has been achieved; and it was pointed out in Chapter VII that operative treatment did not show a gain in this respect.

A possible exception is to be found in a certain category of intellectual workers who may be able to resume part of their occupational activities with a stable osteosynthesis prior to the time of full bony union.

With regard to the period in hospital and the duration of unfitness to work the literature usually presents mean values without standard deviation. Dencker (1963) pointed out that a false impression may be gained as a result of this practice.

XI.2. DURATION OF HOSPITAL PERIOD

Dencker (1963, 1964) observed that conservative treatment led to a longer period in hospital than Küntscher nail osteosynthesis. More than 50% of the conservatively treated patients spent more than 3 months and 3 weeks in hospital, while more than 50% of the patients treated by Küntscher nail osteosynthesis were discharged within 2 months and 2 weeks. It was found, however, that 6% of the Küntscher nail patients were still in hospital after a year, owing to complications; in the conservatively treated group this was the case with only 2% of patients. Wickstrom and Corban (1967) calculated a mean hospital period of 31 days for a group of patients with femoral shaft fractures treated by Küntscher nail osteosynthesis without reaming of the medullary cavity.

Suiter and Bianco (1971) calculated the mean period in hospital for two groups of selected patients with femoral shaft fractures. The mean

period in hospital for 31 conservatively treated cases was 78.4 days, while that for 28 cases treated by Küntscher nail osteosynthesis without reaming of the medullary cavity was 43.1 days.

Patients with associated injuries were excluded from the calculations made by Rokkanen et al. (1971), who established a mean hospital period of 33 days for patients treated by Küntscher nail osteosynthesis with reaming of the medullary cavity, and one of 71 days for a group of conservatively treated patients.

In the present study the 24 patients who died in hospital and the 54 whose associated injuries substantially influenced the period in hospital, were excluded along with 10 patients of the group 'various methods of treatment'. For calculations concerning the duration of the hospital period, therefore, 241 patients remained.

The overall mean duration of the hospital period was 53.48 days (standard error ± 2.98). The data for the four different methods of treatment are presented in table 88.

Table 88. Mean duration of hospital period in relation to methods of treatment.

Method of treatment	Mean duration of hospital period and standard error
Conservative	79.33 days (± 3.04)
K-nail without	38.70 days (± 3.60)
K-nail with	30.24 days (± 1.84)
AO-plate	59.30 days (± 17.47)

Table 88 shows that the mean hospital period for the conservatively treated patients corresponds to the values reported by Suiter and Bianco and by Rokkanen et al. Substantial shortening of the hospital period was achieved in the group treated by Küntscher nail osteosynthesis. In this respect it is to be borne in mind that, particularly in the earlier cases of this series, it was customary to discharge a parient with a plaster spica once the wound of the Küntscher nail osteosynthesis had healed. This has greatly influenced the hospital period for the group 'K-nail without'.

Table 89. Period in hospital in relation to methods of treatment.

Hospital period	Conservative		K-nail without		K-nail with		AO-plate	
	nr.	cum. %	nr.	cum. %	nr.	cum. %	nr.	cum. %
0– 9 days	0		2	2.0%	0		0	
10– 19 days	0		23	25.7%	8	19.5%	5	16.6%
20– 29 days	0		25	51.5%	13	51.2%	9	46.6%
30– 39 days	1	1.3%	19	71.1%	12	80.5%	7	69.9%
40– 49 days	9	13.6%	9	80.3%	5	92.6%	2	76.6%
50– 59 days	10	27.0%	6	86.5%	3	100.0%	4	90.0%
60– 69 days	9	39.3%	1	87.5%	0		0	90.0%
70– 79 days	10	52.7%	2	89.5%	0		0	90.0%
80– 89 days	8	63.6%	2	91.5%	0		0	90.0%
90– 99 days	9	75.9%	1	92.5%	0		0	90.0%
100–109 days	11	91.1%	3	95.8%	0		0	90.0%
110–119 days	1	92.4%	0	95.8%	0		0	90.0%
120–129 days	3	96.7%	1	96.8%	0		0	90.0%
130–139 days	2	100.0%	2	99.0%	0		0	90.0%
200 and over	0		1	100.0%	0		3	100.0%
Total	73		97		41		30	

Comparison between:	Mean ranks:		Test:	Difference is:
Cons. and K-nail without	122.36	57.76	8.516	sign. $p < 0.001$
Cons. and K-nail with	76.92	22.91	8.413	sign. $p < 0.001$
Cons. and AO-plate	62.98	25.28	5.844	sign. $p < 0.001$
K-nail without and K-nail with	70.21	67.83	0.327	not significant
K-nail without and AO-plate	62.69	68.23	0.736	not significant
K-nail with and AO-plate	34.13	38.55	0.917	not significant

A factor which has influenced the group of operatively treated patients was the fact that during the latter half of the period covered by this series it became possible to transfer a number of patients from the hospital to a nursing-home. In this manner the period in hospital was sometimes quite considerably shortened.

The mean hospital period in the A.O.-plate group was nearly twice as long as that in the Küntscher nail groups. It is not inconceivable that this unfavourable effect in the AO-plate group was produced by three patients who developed a deep infection and consequently spent a very long time in hospital.

More information is presented in table 89, in which the data on the hospital period are related to the method of treatment used. The differences between the methods of treatment were tested for significance with the aid of the Mann-Whitney U-test.

As expected, conservative treatment proved to be associated in the present series with a significantly longer hospital period than the three operative methods of treatment. With the rank order test used, no significant difference was demonstrable between the three operative methods of treatment.

XI.3. DURATION OF UNFITNESS TO WORK

Dencker (1963) gave no information on the duration of unfitness to work in the patients of his series.

For a group of patients treated by Küntscher nail osteosynthesis with reaming of the medullary cavity, Rokkanen et al. (1969) reported a mean period of unfitness of 7½ months. Blichert-Toft and Hammer (1970) calculated a mean period of unfitness of 8½ months (range: 2 to 24 months) for the patients in their series, which included operatively as well as conservatively treated patients.

Calculations made in the present series were based on the data supplied by the patients at the time of the follow-up. The time at which the patient had resumed full occupational activies was used in the calculations. The influence of associated injuries on the duration of unfitness to work is usually difficult to assess, and the presence and role of associated injuries was therefore disregarded in these calculations. Nor was a subdivision made according to the nature of work.

The data on 69 patients could not be included in the calculations. The reasons for elimination are presented in table 90.

The patients who did not resume work, and those who changed their occupation, will be separately discussed in section XI.4.

The mean duration of unfitness to work for the entire population in the present series was 9.17 months (standard error ± 0.34). The mean duration of unfitness to work is related to the methods of treatment used (table 91).

Table 90. Reasons for elimination from calculations concerning duration of unfitness to work.

not in labour process (school, pension, etc.)	23
work not resumed due to femoral shaft fracture	2
work not resumed due to associated injury	12
work not resumed for other reasons	7
no reliable information	15
remainder of group 'various methods of treatment'	10
Total	69

Table 91. Mean duration of unfitness to work in relation to methods of treatment.

Method of treatment	Mean duration of unfitness to work and standard error
Conservative	9.45 months ± 0.53
K-nail without	9.43 months ± 0.52
K-nail with	7.38 months ± 0.60
AO-plate	10.23 months ± 1.44

The group 'K-nail with' compares favourably with the other groups. The duration of unfitness to work in this group corresponds with the data published by Rokkanen et al.

The individual data on the duration of unfitness to work are presented in relation to the methods of treatment in table 92.

Table 92 shows that the duration of unfitness to work was significantly shorter in the group 'K-nail with' than in the group 'Conservative' and the group 'K-nail without'.

Table 92. Duration of unfitness to work in relation to methods of treatment.

Duration of unfitness to work	Conservative		K-nail without		K-nail with		AO-plate	
	nr.	cum.%	nr.	cum.%	nr.	cum.%	nr.	cum.%
3 months	0		0		1	2.7%	0	
4 months	1	2.0%	2	3.0%	5	16.2%	0	
5 months	2	6.0%	6	11.7%	3	24.3%	6	22%
6 months	7	20.4%	14	32.0%	8	45.9%	6	44%
7 months	7	34.8%	6	40.7%	7	64.9%	3	56%
8 months	7	49.2%	6	49.4%	5	78.4%	1	60%
9 months	3	55.2%	7	59.5%	2	83.8%	0	60%
10 months	7	69.6%	3	63.8%	2	89.2%	3	72%
11 months	1	71.6%	5	71.0%	1	91.9%	1	76%
12 months	9	90.0%	6	82.7%	1	94.6%	1	80%
13 months	0	90.0%	1	84.1%	1	97.3%	0	80%
14 months	3	96.0%	1	85.5%	0	97.3%	1	84%
15 months	0	96.0%	2	88.5%	0	97.3%	0	84%
17 months	0	96.0%	4	94.5%	0	97.3%	0	84%
18 months	0	96.0%	3	98.8%	0	97.3%	0	84%
20 months	1	98.0%	0	98.8%	0	97.3%	0	84%
24 months	1	100.0%	1	100.0%	1	100.0%	2	92%
26 months	0		0		0		1	96%
30 months	0		0		0		1	100%
Total	49		69		37		26	

Comparison between:	Mean ranks:		Test:	Difference is:
Cons. and K-nail without	61.79	58.75	0.475	not significant
Cons. and K-nail with	51.06	33.49	3.257	significant $p < 0.01$
Cons. and AO-plate	40.43	33.42	1.335	not significant
K-nail without and K-nail with	59.75	43.12	2.655	significant $p < 0.01$
K-nail without and AO-plate	49.89	44.75	0.810	not significant
K-nail with and AO-plate	29.92	34.96	1.086	not significant

XI.4. CHANGE OF OCCUPATION

The last socio-economic aspect to be discussed concerns work resumption and change of occupation. In this respect, too, there are numerous factors not related to treatment as such, which can nevertheless play an important role.

This is illustrated by the observation of Blichert-Toft and Hammer (1970) that the one patient in their series who had to undergo amputation because of a femoral shaft fracture with a vascular lesion, subsequently had to change his occupation and as a result attained a position classified higher in the social hierarchy.

In view of the numerous influencing factors, comparison with the scanty data from the literature would be useless.

It would be interesting to establish which percentage of patients in the present series received partial disability compensation. The size of the compensation would be another interesting datum. However, it was found in the follow-up study that it was difficult to obtain reliable information from the patient in this respect.

Moreover, the impression was frequently gained that the disability compensation was often based on an associated injury rather than on a sequela of the femoral shaft fracture. The

data ultimately collected were too heterogeneous and not sufficiently reliable to warrant conclusions.

Table 90 shows that a few patients did not resume work. In two cases this was due to the femoral shaft fracture; 12 did not resume work because of an associated injury, and seven had other reasons for not resuming work.

The two patients who did not resume work because of the femoral shaft fracture were nrs. 227 and 329. Patient nr. 227 was discussed in detail on page 83. In this patient Küntscher nail osteosynthesis with reaming of the medullary cavity was followed by true non-union. After renailing the fracture did unite after all. In view of a pending insurance problem the patient had not resumed work at the time of the follow-up. In patient nr. 329, discussed in detail on page 88, deep infection occurred after A.O.-plate osteosynthesis. His disability was partly due to the fact that bilateral fractures of the wrist had united in marked deformity.

The associated injuries which led to permanent disability are listed in table 93.

Table 93. Associated injuries which led to permanent disability.

Postcontusional syndrome	4
Brachial plexus lesion	1
Femur amputation for lesion of popliteal artery	1
Femur amputation and severe burns	1
Poor union of medial femoral neck fracture	1
Sequela of chest injury	1
Paraplegia	1
Rupture of quadriceps tendon	1
Poor union lower leg fracture and open talus fracture	1

Seven patients had not resumed work at the time of the follow up for reasons unrelated to the accident: two had been pensioned off shortly after the accident, one was permanently disabled by insufficiency of the basilar artery, one by angina pectoris, one by idiopathic febriles attacks, one by hypochondria, and one by oligophrenia and workshyness.

Five patients changed their occupation because of the femoral shaft fracture. A cabinet-maker became a counterman; an upholsterer became a shopkeeper; a porter became a forklift-truck driver; a postman was employed in a drawing-office; a dockworker became a chauffeur.

XI.5. SUMMARY AND CONCLUSIONS

This chapter presents a survey of a few socio-economic aspects of the femoral shaft fracture as they emerged from this study. Aspects discussed were duration of hospital period, duration of unfitness to work, and change of occupation. All these socio-economic aspects are subject to the influence of numerous factors unrelated to treatment. This impedes interpretation.

The mean duration of hospital period for the entire series proved to be 53.48 days (patients with influencing associated injuries excluded). Related to the method of treatment, the mean duration of hospital period proved to approximate 80 days for conservative treatment, while for Küntscher nail osteosynthesis it ranged from 30 to 38 days; for A.O.-plate osteosynthesis the mean duration of hospital period was almost 60 days in this series. This relatively long period in hospital after A.O.-plate osteosynthesis was probably caused by three patients who spent a very long time in hospital owing to a deep infection.

Application of the Mann-Whitney U-test revealed a significant difference in duration of hospital period between conservative treatment on the one hand, and all operative methods of treatment on the other.

The mean duration of unfitness to work as established in the suitable patients of this series, was 9.17 months. Differences in relation to methods of treatment were not very marked. The group 'K-nail with' compared favourably with the other groups, showing an average gain of two months.

Permanent disability as a result of femoral shaft fracture is rather exceptional. In the present series only two patients were permanently disabled. Associated injuries, however, were a not infrequent cause of permanent disability, and causes unrelated to the accident could also be distinguished.

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Chapter XII
Femoral shaft fractures in various combinations

XII.1. INTRODUCTION

It was pointed out in Chapter IV that homolateral associated injuries of the leg are quite common in femoral shaft fractures. Among these associated injuries there are some which are so frequently observed or which pose such special problems that combinations of a femoral shaft fracture with such associated injuries can be described as more or less typical.

These combinations make special demands on the treatment of the femoral shaft fracture, and the functional prognosis of these combinations of injuries often differs from that of the separate constituent injuries.

In many cases the femoral shaft fracture dominates the clinical picture, as a result of which associated injuries are not infrequently overlooked.

The combinations successively discussed in this chapter are those with hip injury, with injury of the extensor apparatus and with a homolateral lower leg fracture. Next come combinations with nerve injuries and vascular injuries, and a final section (perhaps slightly exceeding the scope of this chapter) is devoted to fat embolism in association with femoral shaft fracture.

The problems of fat embolism are extremely complex, and it is not the intention of this study to outline new trends in the aetiology and treatment of this condition. The problem of fat embolism is broached in order to present a number of important data available on this subject.

XII.2. FEMORAL SHAFT FRACTURE AND HOMOLATERAL HIP INJURY

Ritchey et al. (1958) collected the data on 30 patients who sustained a femoral shaft fracture in a frontal car collision. Six of these patients had a homolateral hip injury; all these patients had been thrown with the knees against the dashboard of the car. Ritchey et al. presumed that a correlation existed between the type of hip injury and the position of the thigh in relation to the body axis. They believed that abduction in the hip-joint could lead to an acetabular fracture, central hip dislocation, a femoral neck fracture or pertrochanteric fracture; in the case of adduction (i.e. with the legs crossed), there should be a risk of (posterior) hip dislocation.

Possibilities discussed in succession here are: hip dislocation, acetabular fracture and femoral neck or pertrochanteric fracture.

The combination of a femoral shaft fracture with homolateral hip dislocation is exceedingly rare. Dehne and Immerman (1951) reviewed 7 personal observations and 35 other cases, partly collected from the literature and in part from personal communications. They reported that the diagnosis was made at the first examination in only 15 cases. The dislocation of the hip was usually posterior dislocation. Owing to the femoral shaft fracture, the pathognomonic adduction and endorotation did not become manifest.

Detzel (1953), reporting on a series of 400 femoral shaft fractures, noted three instances of combination of femoral shaft fracture with hip dislocation. In these patients the diagnosis was initially overlooked, and severe ultimate disability resulted. According to Detzel the aetiolo-

gical factor was a force impinging longitudinally on the thigh; and this is illustrated by the fact that a homolateral knee injury was often associated.

Homolateral hip dislocation occurred in one patient of the present series, whose case history is briefly outlined.

1. Patient nr. 169, a man aged 37, drove his car into a tree. In addition to cerebral concussion and fracture of the nasal bone he sustained a transverse femoral shaft fracture and a fracture dislocation of the homolateral hip. There was a posterior dislocation, and a fragment was detached from the posterior aspect of the acetabulum.

Küntscher nail osteosynthesis without reaming of the medullary cavity was carried out on the day after the accident; it was immediately followed by closed reduction of the hip dislocation, which posed no difficulty.

Postoperatively, traction was exerted on the leg by means of an skin traction bandage. Two weeks after the accident, superficial infection of the surgical wound was diagnosed. Staphylococcus aureus was isolated from the wound fluid. The wound was opened up to ample width, and parenteral antibiotics were given. The wound healed within a few weeks without signs of deep infection. Five weeks after the accident the patient, in good general condition, was transferred to another hospital.

Radiographs made available on request showed that union of the femoral fracture was attained in six months. No further radiological examination of the hip was made.

When contacted by telephone eight and a half years after the accident, the patient reported that he was entirely free from symptoms. He had resumed his work as a technician 10 months after the accident.

The combination of femoral shaft fracture with homolateral acetabular fracture is rarely mentioned in the literature. In the series described by Ritchey et al. (1958) this combination was found in four out of 30 selected patients with a femoral shaft fracture.

In the present series this combination was encountered in five cases (including the abovementioned patient nr. 169 with a dislocation fracture), i.e. 1.5% of the present series.

Three of these patients were involved in a frontal car collision; one drove his tractor into a ditch, and one was riding a moped when the was hit by a car. In two patients there were multiple pelvic fractures.

In four patients the acetabular fracture was treated by wire extension. In two patients the femoral shaft fracture was operatively treated, in both cases by Küntscher nail osteosynthesis without reaming of the medullary cavity. In one patient open reduction and fixation of the acetabular fracture was combined with conservative treatment of the femoral shaft fracture.

All these patients except nr. 169 were examined in the follow-up study. One patient (nr. 245) was seriously handicapped because a quadriceps tendon rupture failed to heal. This patient will be discussed in section XII.3. The remaining patients were free from symptoms, and all had resumed work. In one of these four patients rotations in the hip-joint were limited. In none of these patients did radiological examination of the hip-joint reveal evidence of osteoarthritis of this joint.

Of the homolateral hip injuries found in combination with a femoral shaft fracture, a femoral neck or pertrochanteric fracture is the most common. Yet even this combination is relatively rare. Böhler and Aichner (1959) reported having diagnosed such a proximal fracture in 5% of their patients with a femoral shaft fracture. Dencker (1965) found a femoral neck or pertrochanteric fracture in 8 out of 1003 femoral shaft fractures, i.e. 0.8%. Small series (ranging from four to eight patients) were described by Delaney and Street (1953), Heise (1957), Kimbrough (1961), Spängler (1963), Schatzker and Barrington (1968) and Tscherne et al. (1969).

A survey of the literature on this combination and a study of a large number of personal observations (Kootstra and Binnendijk, in preparation) showed that the femoral shaft fracture was an open fracture in 43% of these cases.

Three types of accident proved to be responsible for this combination of injuries: a fall from a great height, a frontal car collision, and a motorcycle or moped accident. The proximal fracture remains unrecognized in 12-80% of cases.

Several methods of treatment have been described. Theoretically, the Y-nail according to Küntscher (1967) is an ideal means to stabilize both fractures at once. Stabilization of both fractures with the aid of a 130° plate and a straight

plate has been described in the A.O. 'manual' (Müller et al. 1965).

Results reported are generally only moderate. There are several possible causes: deformity after union of an unrecognized proximal fracture, infection of the femoral shaft fracture, and pseudarthorosis of the femoral neck fracture.

In the present series, a proximal fracture was found in 11 of 329 femoral shaft fractures, i.e. 3.4%. In two patients the proximal fracture was not diagnosed until later. Six patients had a homolateral patellar fracture as well.

In two cases the proximal fracture was a comminuted pertrochanteric fracture. At follow-up, one patient showed serious limitation of movement in the hip-joint. Both patients had resumed work.

In one patient the proximal fracture was a lateral femoral neck fracture. In this pateint (nr. 030) union of the femoral shaft fracture was delayed, and the femoral neck fracture ended in pseudarthrosis. This patient was discussed on page 84.

In three patients the proximal fracture was a simple pertrochanteric fracture. One patient (nr. 181) died; one patient made a good recovery after conservative treatment; in the third patient operative treatment of both fractures produced only a moderate result, mainly due to lack of cooperation on the part of this oligophrenic patient.

In the remaining five patients the proximal fracture was a steep medial femoral neck fracture. Böhler (1953) demonstrated in experiments with human cadaver femurs that this fracture type occurs in response to a longitudinally impinging force. In one case the fracture was not recognized until a Küntscher nail osteosynthesis was performed six days after the accident; this fracture united in deformity. At follow-up, this patient proved to show limitation of movement in the hip-joint.

The results obtained in two of these patients were only moderate, mainly due to limitation of movement in the hip-joint and femoral shaft fracture union with considerable shortening. In one patient a good result was obtained by screw osteosynthesis of the proximal fracture and conservative treatment of the femoral shaft fracture.

The case history of the last (nr. 329) of these five patients was given in detail on page 77. In this patient the steep medial femoral neck fracture was diagnosed six days after the accident. The dislocation was only slight, and the fracture was treated conservatively. The poor result in this case was caused by the deep infection of the femoral shaft fracture.

Homolateral hip injuries occur in combination with femoral shaft fractures in some 5% of cases. Failure to diagnose the hip injury can lead to severe disability. It is of essential importance in all cases of femoral shaft fractures to obtain a radiograph of the pelvis as a routine procedure. There are several possibilities of treatment. Neither the relevant literature nor the findings obtained in the present series indicate one particular treatment as the method of choice for this combination of injuries.

XII.3. FEMORAL SHAFT FRACTURE AND INJURY OF THE EXTENSOR APPARATUS

A femoral shaft fracture accompanied by an injury of the homolateral extensor apparatus can certainly be regarded as a menace to the function of the entire limb, and that of the knee joint in particular. The femoral shaft fracture alone is held responsible for a certain percentage of permanent disturbances of knee function. In their discussion of the results obtained in the treatment of patellar fractures, Scott (1949) and Burwell (1962) eliminated patients with a homolateral femoral shaft fracture in view of the poor prognosis which this combination was believed to have. Smillie (1954) and Ritchey et al. (1958) likewise expressed themselves in gloomy terms about the expected recovery of knee function.

Dencker (1963) reported having found a homolateral patellar fracture in 17 cases (1.7%) but gave no further information on recovery of function.

Studying the material of the Royal National Orthopaedic Hospital over a period of 17 years, Fitzgerald (1970) collected 14 cases of femoral shaft fracture combined with a homolateral patellar fracture, most of which had been admitted to this hospital for aftercare. Among these 14 patients there were four with a supracondylar or

intracondylar femoral fracture rather than a femoral shaft fracture. In three of these patients the result was virtually complete loss of knee function. The results in the ten patients with a true combination of femoral shaft fracture and patellar fracture were better. Only one patient had less than 100° flexion, and in three patients there was full recovery of knee function. Fitzgerald advised operative treatment of both fractures: depending on the type of patellar fracture, osteosynthesis or extirpation à chaud, and delayed internal fixation of the femoral shaft fracture.

In the present series there were 19 patients with a patellar fracture, two with rupture of a quadriceps tendon and one with rupture of the patellar ligament. One patient (nr. 334) showed rupture of a quadriceps tendon as well as comminution of the patella, so that there were a total of 21 patients with an injury of the extensor apparatus (i.e. 6.4%).

In six cases the patellar fracture was an open fracture. The accidents giving rise to the combination were: a fall from a great height in two cases, a frontal car collision in five, and a motorcycle or moped accident in 12 cases.

A conspicuous finding was that a femoral neck or pertrochanteric fracture had simultaneously occurred in six cases. In four patients there was additional serious knee injury, necessitating primary amputation in one case (patient nr. 334). The patellar fracture was treated by osteosynthesis in one case, and by partial patellectomy with reinsertion of the patellar ligament in two. Extirpation of the patella was carried out in 12 cases, and in the remaining cases a small patellar fracture without dislocation was treated conservatively.

At the time of the follow-up one patient had died (nr. 072) and one had undergone an amputation (nr. 334); immediately prior to the follow-up one patient (nr. 030) had sustained a supracondylar femoral fracture which had led to marked limitation of movement in the knee-joint. This patient reported that she had had up to 90° knee flexion prior to the second accident.

In six of the remaining 16 patients there was full recovery of knee function. In six other patients there was 20–30° limitation of movement. Two patients (nr. 017 with a homolateral femoral neck fracture and a homolateral ankle fracture, and nr. 204 with union of the femoral shaft fracture in considerable recurvation) showed 50–60° limitation of movement. One patient (nr. 005) in whom a refracture had been treated by prolonged immobilization in a plaster spica, showed 90° limitation of movement. The limitation of movement in the last patient (nr. 053) was about 105°. This patient had a homolateral comminuted pertrochanteric fracture, and the femoral shaft fracture had united with varus deformity.

It is difficult to form a conclusion as to the treatment of choice for this combination on the basis of the above findings. It seems probable, however, that exercise-stable fixation of the femoral shaft fracture and operative treatment of the patellar fracture create favourable conditions for recovery of knee function.

As pointed out, two patients combined a femoral shaft fracture with a quadriceps tendon rupture. In one case this was associated with a patellar fracture and comminution of the lower leg and knee, necessitating amputation. This patient (nr. 334) was discussed on page 78. The case history of the other patient follows here.

1. Patient nr. 245, a man aged 27, was riding a moped when he was hit by a car. He was found lying along the road in deep shock, with multiple injuries: contusion of the brain with a large head wound, fracture of the left scapula, fracture of the left humeral shaft, lesion of the left brachial plexus and a severe injury of the entire left leg (acetabular fracture, open comminuted femoral shaft fracture, fracture of the lateral femoral condyle, suprapatellar intra-articular knee injury and fracture of the ankle).

Infusions were given to control the shock, and an extensive wound toilet was made. A steel suture was used to fix the quadriceps tendon to the patella, and a wire extension was passed through the tibial tuberosity. Osteosynthesis of the femoral shaft fracture was refrained from in view of the marked wound contamination.

The patient remained comatose for a long time. Tracheotomy was necessary. Later, dysfunction of the left peroneal nerve was diagnosed. The femoral shaft fracture united in four months. The brachial plexus lesion did not heal. The patient spent a long time in a rehabilitation centre.

At follow-up, three and a half years after the accident, the patient walked with an extension brace. The femoral shaft fracture had united without shortening but with 20° exorotation. A depression was visible at the site of the quadriceps tendon.

The circumference of the thigh, measured 15 cm proximal to the medial intra-articular space, was 8 cm less than that of the intact thigh. Active extension in the knee-joint was possible up to 130° (passive extension was complete: 180°). There was virtually complete recovery of peroneal nerve function. Radiological examination of the hip-joint revealed no evidence of osteo-arthritis. The patient had not resumed work as a factory worker.

The case history of the patient with a femoral shaft fracture and an injury of the patellar ligament was as follows.

2. Patient nr. 277, a man aged 34, was sitting beside the driver in a car which crashed against a tree. He sustained a closed comminuted femoral shaft fracture and a Colles' fracture of the radius.

A wire extension was passed through the tibial tuberosity. Control radiographs of the femur showed elevation of the patella, in view of which 'rupture of the patellar ligament' was diagnosed 24 days after the accident. A few days later the patient developed symptoms of pulmonary embolism, in view of which operative treatment of the rupture of the patellar ligament was postponed. Ten weeks after the accident, fracture treatment was continued in a device for supported exercise. Angulation of the fracture, however, necessitated A.O.-plate osteosynthesis. Exercise stability was attained. Fracture union was achieved in six months. Nine months after the accident, operative repair of the tendon was done in another hospital; the operation was successful.

At follow-up three and a half years after the accident the patient reported that he had resumed work as a driver and was free from symptoms. The difference in circumference between the two thighs was 5 cm. There was 20° limitation of knee flexion, while knee extension was complete.

Early diagnosis is of cardinal importance in the treatment of quadriceps tendon injuries. An exercise-stable osteosynthesis of the femoral shaft fracture seems important for adequate recovery of function.

XII.4. FEMORAL SHAFT FRACTURE AND HOMOLATERAL LOWER LEG FRACTURE

The combination of femoral shaft fracture with homolateral lower leg fracture was recently discussed in publications by Omer et al. (1968), Ratcliff (1968) and Winston (1972).

Omer collected data on 19 patients with 20 femoral shaft fractures. Operative treatment of the femoral shaft fracture was followed by deep infection in two cases. In six cases there was complete recovery of knee function, while nine patients showed fair recovery of knee function. Omer maintained that stabilization of the femur is the key to good functional result. He also maintained, however, that conservative treatment is safe and reliable.

Ratcliff reported on 43 patients with this combination. He recommended internal fixation of both fractures. He published his findings in society proceedings in which no detailed information was presented.

Winston's publication differed from the other two in that he reported on 24 patients who were all conservatively treated. He motivated the conservative approach with the arguments that it is a safe method which leads to satisfactory results, and that in many cases a femoral shaft fracture associated with a lower leg fracture is unsuitable for osteosynthesis. Winston observed delayed union in five of the femoral shaft fractures and ten of the lower leg fractures.

Fair recovery of knee function resulted in 17 of the 24 patients. Ten patients showed shortening. Winston noticed an unusual age distribution, with one peak between age 16 and age 27, and another between age 65 and age 80.

Dencker (1963) observed a homolateral lower leg fracture in 5% of his cases of femoral shaft fracture. Suiter and Bianco (1971) found it in 11% of their cases from the Mayo Clinic. In the present series, a homolateral lower leg fracture was found in 10.9% of patients; this is substantially higher than the rate reported by Dencker. It has already been pointed out that the difference in incidence of traffic accidents between the two series is probably responsible for this difference.

A homolateral lower leg fracture was observed in 36 patients of the present series. The type of

accident involved in one case remained unknown; all other patients were involved in traffic accidents – always with a car involved. Accident types are listed in table 94.

Table 94. Homolateral lower leg fracture in relation to type of accident.

Type of accident	Number of patients with homolateral lower leg fracture
riding motorcycle or moped when hit by car	16
in car colliding with other car or tree	13
walking when hit by car	6

The peculiar age distribution reported by Winston was not observed in the present series. The incidence of homolateral lower leg fractures in relation to the type of femoral shaft fracture is shown in table 95.

Table 95. Homolateral lower leg fracture in relation to type of femoral shaft fracture.

type of femoral shaft fracture	no lower leg fracture		lower leg fracture	
bending	204	91%	21	9%
comminuted	52	83%	11	17%
torque	32	100%	0	0%

$\chi_{(1)}^2 = 7.56$. Significant ($p < 0.05$)

Table 95 shows that no homolateral lower leg fractures were observed in combination with torque fractures of the femoral shaft, whereas comminuted femoral shaft fractures were relatively often associated with homolateral lower leg fracture. Of two of the femoral shaft fractures it was unknown whether they were closed or open. Of the remaining 34, nine were open (i.e. 26%).

Of the 36 lower leg fractures, 26 were open (i.e. 75%)! The distribution of the femoral shaft fractures over the various methods of treatment was more or less even (cf. Table 42).

The patients on whom data concerning the duration of fracture union were available, as a rule showed no delay of union of the femoral shaft fracture. Only in one patient (nr. 097), with a defect fracture for which a fibular graft was used, did a disturbance of fracture union occur.

The lower leg fractures were likewise differently treated, treatment being conservative in about 50% of cases and operative in the remainder. Operative treatment involved either Küntscher nail osteosynthesis or A.O.-plate osteosynthesis, while in a few cases a 'fixateur externe' was used.

Of the 36 patients, five died in hospital (nrs. 162, 181, 192, 235 and 292); three patients died during the interval between discharge from hospital and follow-up (nrs. 077, 080 and 120); two patients underwent an amputation (nrs. 194 and 334).

Table 96 surveys the patients with permanent limitation of movement in the knee-joint in relation to the presence or absence of a homolateral lower leg fracture.

Table 96. Homolateral lower leg fracture in relation to limitation of movement in the knee-joint.

	no lower leg fracture		lower leg fracture	
no limitation of movement	139	74%	17	63%
limitation of movement	50	26%	10	37%

$\chi_{(1)}^2 = 0.84$. Not significant.

There proved to be no significant difference in the incidence of limitation of movement in the knee-joint.

The ten patients with limitation of movement in the knee joint were divided into four with 10°, two with 20° and four with 30–50° limitation of movement. The lastmentioned four patients all had severe homolateral associated injuries: femoral neck fracture in two, defect fracture bridged by a fibular graft in one, and very much delayed union of the lower leg fracture and substantial soft-tissue injury in one.

In the seven patients in whom both the femoral shaft fracture and the lower leg fracture were operatively treated, complete recovery of knee function was always observed. The same applied to the three patients in whom both fractures were treated conservatively. In the remaining patients, one of the fractures was treated conservatively, and the other by operation.

On the basis of the above data it is difficult to reach a conclusion as to the treatment of choice of a limb with a femoral shaft fracture as well as a lower leg fracture. In the present series, good results were obtained both by conservative and by operative treatment of both fractures. What seems indicated is a sensible, safe approach, that is to say: stabilization (and thus elimination) of one of the fractures. The fracture best suited to simple stabilization should be chosen for this. If the lower leg fracture is associated with very severe soft-tissue injury, then à chaud application of a 'fixateur externe' is to be contemplated. In such cases the femoral shaft fracture can be dealt with by conservative treatment or delayed operative treatment.

XII.5. FEMORAL SHAFT FRACTURE AND NERVE INJURY

Femoral shaft fractures can be associated with injuries of the sciatic nerve or of the peroneal nerve. Injuries of the sciatic nerve are rare in civilian accidents. Dencker (1963) found a lesion of the sciatic nerve in four out of 1003 femoral shaft fractures, i.e. 0.4%. In three patients this injury was probably due to an associated acetabular fracture. The four patients all showed sciatic nerve dysfunction at follow-up.

In 1952 Kingma reported from a military hospital in The Netherlands East Indies on four patients with a femoral shaft fracture and a lesion of the sciatic nerve. These cases involved bullet wounds. Kingma argued in favour of exploration of the nerve.

The present series included two patients with a sciatic nerve injury, whose case histories follow.

1. Patient nr. 218, a man aged 58, crashed his moped against a car. He was an invalid (polyneuritis). He sustained a very severe injury of the entire left leg: open transverse fracture with butterfly halfway the shaft of the femur, injury of the medial ligament of the knee, fibular fracture, open dislocation of the talus and open calcaneal fracture. Angiography in addition revealed an injury of the superficial femoral artery. Exploration revealed contusion of the arterial wall with thrombosis at the level of the femoral shaft fracture. The affected segment of the superficial femoral artery was resected and replaced by an autogenous saphenous vein graft. The femoral shaft fracture was reduced and fixed by Küntscher nail osteosynthesis without reaming of the medullary cavity. The nail jammed, and an attempt at extraction failed. The nail was then bent above the greater trochanter by hammering. Arthrodesis of the inferior ankle-joint was effected.

Loss of sciatic nerve function became manifest in the postoperative phase: the foot muscles were entirely paretic, and the skin below the knee-joint was entirely without sensibility. Pulsations of the posterior tibial artery were normal, the vitality of the foot was good. Union of the femoral shaft fracture was complete in six months.

At follow-up six years after the accident the patient complained of a cold foot. He walked with a stick. The foot was alive but paretic. The pulsations of the posterior tibial artery were normal. The skin below the knee was still without sensibility. The left leg was 2 cm shorter. The femoral shaft fracture had united with 30° exorotation. Flexion in the knee-joint was reduced by 10° and there was marked atrophy of the quadriceps muscles.

The findings warranted the conclusion that the sciatic nerve lesion had failed to heal in the course of the years. As a result of the vascular operation, however, the patient had retained fair use of the leg and had been spared the mutilating intervention of exarticulation in the knee-joint or femoral amputation.

2. Patient nr. 279, a man aged 19, was sitting beside the driver in a car which was hit by another car from the right. He sustained a closed transverse femoral shaft fracture with butterfly and haemarthros of the knee-joint.

A lesion of the sciatic nerve manifested itself four days after the accident: the foot was paretic and the skin of the lower leg was without sensibility.

Closed Küntscher nail osteosynthesis of the femoral shaft fracture with reaming of the medullary cavity led to exercise stability. The patient was given intensive physiotherapy, including electrical stimulation of the paretic muscles.

Six weeks after the accident the patient was transferred to another hospital, where exploration of the sciatic nerve was performed. The nerve was found to show some slight narrowing at the level of the fracture, but its continuity was intact, and no further surgery was performed. Reinnervation gradually occurred.

At follow-up four years after the accident the patient had resumed his work as a hospital attendant. There was virtually complete recovery of motor function, but some sensory dysfunction remained in the lateral aspect of the lower leg and the lateral edge of the foot; this was gradually improving. The conclusion can be reached that restoration of the sciatic nerve was in progress in this patient.

Whereas loss of sciatic nerve function is rare in patients with a femoral shaft fracture, a lesion of the peroneal nerve is quite common.

Dencker (1963) found loss of peroneal nerve function in 20 patients, i.e. 2%. In seven cases the nerve was probably injured in the accident, while in six patients the loss of function followed Küntscher nail osteosynthesis; in two patients it occurred after plate osteosynthesis, and in one after cerclage. At the follow-up study Dencker found another four patients with loss of peroneal nerve function.

Suiter and Bianco found loss of peroneal nerve function in eight out of 127 patients with a femoral shaft fracture, i.e. 6.2%.

In the present series loss of peroneal nerve function was defined as dysfunction of either the superficial or of the deep ramus, or of both rami. The diagnosis was as a rule made on the basis of clinical symptoms, whereupon electromyographic examination of the lower leg muscles was done in virtually all patients. In this manner loss of peroneal nerve function was diagnosed in 24 patients in a total population of 313 patients (329 minus 14 early deaths and 2 primary amputations). This is an incidence of 7.6%.

The cause of the loss of function could not always be identified. In a few patients there seemed to be an unmistakable correlation between the loss of nerve function and operation. In one patient loss of peroneal nerve function occurred following application of a tibial tuberosity wire extension.

Four patients showed loss of peroneal nerve function following Küntscher nail osteosynthesis with reaming of the medullary cavity. In two patients the loss of nerve function was probably a result of the accident. The case histories of four patients mentioned loss of peroneal nerve function during postoperative immobilization of the limb by means of a plaster splint. Whether this was due to pressure exerted by the plaster splint on the peroneal nerve or to the operation, cannot be established in retrospect. And there are more patients in whom the cause of loss of nerve function could not be traced. In a number of patients the loss of nerve function may have been caused by pressure exerted by the iron bar of the Braun splint.

The follow-up revealed loss of peroneal nerve function in four patients in whose case histories no mention had been made of it.

Efforts were made in the present series to establish a relationship between loss of peroneal nerve function and:

* type of accident
* local associated injury
* knee injury
* homolateral lower leg fracture
* openness or closedness of the fracture
* method of treatment
* fracture type
* use of a plaster spica.

There was a significant difference in distribution found in relation to a homolateral lower leg fracture. The relevant data are presented in table 97.

Table 97. Loss of peroneal nerve function in relation to homolateral lower leg fracture.

	no lower leg fracture		lower leg fracture	
no loss of peroneal nerve function	264	94%	32	82%
loss of peroneal nerve function	16	6%	7	18%

$\chi_{(1)}^2 = 5.93$. Significant ($p < 0.05$).

For the other factors no Chi-square could be calculated from the cross tables because of the too small expected numbers. In these cases, however, the percentages would seem to suggest that there were no marked differences. For the sake of brevity these data are not presented.

With the exception of the patients whose loss of peroneal nerve function was not discovered until the follow-up, all these patients were given intensive physiotherapy. A follow-up examination could be made in 22 patients. One patient had undergone an amputation, so that 21 patients remain for evaluation. At follow-up it was frequently found that the motor function had been restored. Only five patients showed unmistakable loss of strength in the peroneal muscles. More than 50% of patients still had mild to fairly disturbances of sensibility.

A striking fact was that the patients believed they continued to notice further gradual improvement in peroneal nerve function even after several years.

Both Dencker's series and the present series included a few instances in which a peroneal nerve lesion was not diagnosed until the follow-up. Apparently the attending physician had been insufficiently alert to the possibility of loss of peroneal nerve function. In cases combining a nerve injury with a femoral shaft fracture it is probably important to make an early start with electrical stimulation of the denervated muscles, even though an expert such as Seddon (1948) doubts its efficacy in cases with large groups of muscles involved. Contractures must be prevented. An exercise-stable osteosynthesis of the femoral shaft fracture might therefore be indicated.

XII.6. FEMORAL SHAFT FRACTURE AND INJURY OF THE SUPERFICIAL FEMORAL ARTERY

A perforating injury of the thigh, involving fracture of the femur and injury to the superficial femoral artery, procudes a haemorrhage which immediately leads to a diagnosis of 'vascular injury'. But this diagnosis is less readily made in the case of a closed fracture. The resulting time-loss jeopardizes the survival of the limb. In some cases the absence of distal arterial pulsations is ascribed to a vasospasm, and more time is wasted on an attempt to abolish this spasm. Kirkup (1963) was among the first to report on a series of a few patients with a femoral shaft fracture and an injury of the superficial femoral artery, dealt with by a successful attempt at reconstruction.

Until that time such a combination of femoral shaft fracture and vascular injury often ended in an amputation, with or without an attempt at reconstruction. Table 98 presents a survey of the incidence of injuries of the superficial femoral artery in cases of femoral shaft fracture, and of the number of ultimate amputations.

In the present series the combination of a femoral shaft fracture with a lesion of the superficial femoral artery occurred in three patients (that is roughly in one out of every onehundred patients).

One patient (nr. 218) was discussed in detail in the preceding section. The remaining two case histories briefly were as follows.

1. Patient nr. 196, a boy of 17, was riding a moped when he was hit by a car from the left.

Table 98. Survey of femur amputations in femoral shaft fracture combined with injury of the superficial femoral artery.

	Number of femoral shaft fractures	Number of injuries of superficial femoral artery	Number of amputations
Buck-Gramcko (1954)	103	2	2
Dencker (1963)	1003	5	4
Blichert-Toft and Hammer (1970)	82	1	1
Suiter and Bianco (1971)	131	1	1

He sustained a closed transverse fracture of the shaft of the left femur. At examination the leg was conspicuously pale, cold and without sensibility. There were no distal pulsations. In addition there was a fracture of the left ankle and a hand injury. Arteriography revealed a stop in the superficial femoral artery at the level of the adductor canal. Exploration through a medial incision disclosed injuries of the artery and vein. Through the same incision, an exercise-stable osteosynthesis was achieved by means of a Küntscher nail with reaming of the medullary cavity. This was followed by resection of 4 cm of

the superficial femoral artery. The defect was bridged with a saphenous vein graft obtained from the contralateral leg. The femoral vein was ligated.

The postoperative course was uneventful and union of the femoral shaft fracture was attained in six months.

At follow-up five years after the accident the patient was free from symptoms. He had resumed work as a forklift-truck driver and was playing football. There were good peripheral pulsations. There was some quadriceps muscle atrophy, and 15° limitation of movement in the knee-joint.

2. Patient nr. 303, a man aged 21, was riding a moped when he was hit by a car, sustaining a closed transverse fracture of the left femoral shaft. There were no distal pulsations and the lower leg was cold and without sensibility. Angiography confirmed a diagnosis of 'lesion of the superficial femoral artery'. To begin with, an exercise-stable plate osteosynthesis of the femoral shaft fracture was ensured through a postero-lateral incision. Next, the vessels were explored through a medial incision. The continuity of the femoral vein was found to be entirely interrupted, and the femoral artery was contused over a distance of a few centimetres. This segment was resected and the defect was bridged with a saphenous vein graft from the contralateral leg. Adequate restoration of circulation was effected. The femoral vein was sutured end-to-end.

Loss of peroneal nerve function was observed in the postoperative phase. The patient also developed a cytomegalovirus infection. Fracture union was complete in four months.

At follow-up two years after the accident the patient was free from symptoms. He had resumed work as a salesman six months after the accident and was active in sports. Knee function was equal on both sides. There was no measurable quadriceps muscle atrophy and distal pulsations were good.

In the present series the diagnoses 'femoral shaft fracture and injury of the superficial femoral artery' was fortunately always made immediately. In all cases, reconstruction was successfully effected. A striking feature was that in all these cases the fracture was a bending fracture at a rather distal shaft level.

A study of the rather scanty literature available on this subject likewise showed that an arterial injury mostly occurs in association with transverse fractures at a rather distal shaft level. It seems probable that precisely at this level the anatomical conditions are conducive to occurrence of this injury. At this level the superficial femoral artery is attached to the shaft in the adductor canal, and cannot escape when a fracture fragment impinges on it.

Early diagnosis of the accompanying vascular lesion is of cardinal importance with a view to treatment. Exploration is always indicated, preceded if necessary by arteriography. In the patients of the present series, good results were obtained by resection of the contused segment of the artery and bridging of the defect with an autogenous saphenous vein graft. It seems useful first to ensure stable osteosynthesis of the femoral shaft fracture, thus creating the conditions which favour undisturbed healing of the arterial injury.

XII.7. FEMORAL SHAFT FRACTURE AND FAT EMBOLISM

The heading of this section may seem to suggest that a close correlation exists between femoral shaft fracture and fat embolism. The term femoral shaft fracture has been clearly defined, but what exactly is a fat embolism? In 1968 Bergentz presented a survey of the various syndromes listed under the heading 'fat embolism'. He proposed that a clear distinction be made between the pathological anatomical diagnosis and the clinical syndrome. As a pathological anatomical phenomenon, fat embolism means: 'that fat droplets appear intravascularly in the small vessels, where they can be stained. In this sense it is a common phenomenon mainly after trauma, but not exclusively. It appears too after cardiac massage, after cardiopulmonary bypass with non-membranous oxygenators, after transfusion of stored blood and after pancreatitis'.

It has also been observed in cases with disseminated intravascular coagulation (Hardaway 1966).

Unlike the pathological-anatomical features, the clinical syndrome is rare. Bergentz divided the clinical syndromes into a *pulmonary* and a *systemic* form of fat embolism. In the *systemic*

form the fat droplets enter not only the lungs but also other organs, e.g. the brain, kidneys, myocardium and skin. The symptoms of *pulmonary* fat embolism are: tachypnoea, dyspnoea, tachycardia, 'snow storm' on the chest X-ray, and ECG changes. Blood gas values are likewise important. The unrest and confusion which accompany this form are caused by cerebral anoxia.

Systemic fat embolism according to Bergentz is dominated by cerebral symptoms, but these are not readily distinguishable from the hypoxia in the pulmonary form. Bergentz ultimately arrived at the following definition of fat embolism. 'A polyaetiological disease, intimately related to the various pathophysiological and patho-anatomical alterations occurring in any severe injury. The intravascular fat droplets are certainly not the most important feature of this entity, and they are probably in most cases without pathophysiological significance! It is in particular these fat droplets and their role in fat embolism that have prompted considerable experimental investigation (Meek et al. 1972).

Saikku (1954) found no fat embolism in operatively treated patients with fractures of long bones, but he did observe it in conservatively treated patients. On this basis he advanced the hypothesis that the incomplete immobilization in conservative treatment causes the pressure in the fracture haematoma to increase, as a result of which the fracture haematoma (and consequently also bone marrow) is pressed into the venous circulation. Saikku attached so much importance to the penetration of fat droplets into the circulation that in a few cases he ligated the femoral vein of the affected leg, thus preventing more fat droplets from entering the circulation. He removed the ligature after five weeks.

Meek et al. (1972) held that there are in fact two theories: a mechanical theory, which assumes that large fat droplets enter the blood stream direct from the fracture, and a chemical theory which assumes that biochemical changes accompanying fractures cause fat circulating in the blood stream to coalesce to fat droplets.

Both Sevitt (1962) and Meek et al. (1972) demonstrated that bone marrow fat can enter blood vessels, and that the diameter of the fat droplets exceeds that of the lung capillaries. Hamberger et al. (1972) experimented on rabbits with radioactively labelled fat which was introduced into the medullary cavity. They measured a high radioactivity over the heart after an interval. When the bone in question was fractured, no accumulation of radioactivity over the heart was found. But when the bone was fractured after bandaging, a high radioactivity was again measured over the heart. Hamberger et al. maintained that in the second experimental set-up the radioactively labelled fat was stored in the fracture haematoma. They suggested as a possible clinical implication that fat embolism should be less frequent in open than in closed fractures.

Killian (1931) determined the lethal intravenous dose of fat. In test animals in shock, this dose was found to be much smaller than that in animals with an intact circulation. Pazell and Peltier (1972) likewise attached great importance to the occurrence of fat embolism and a history of shock. Their definition of fat embolism was more restrictive than that used by Bergentz: 'Fat embolism is a self-limiting pulmonary complication of non-thoracic trauma, particularly of fracture of the long bones'. They reported on their experience with 63 patients with fat embolism. All had three or more fractures. In their view the presence of petechiae confirms the diagnosis of 'fat embolism'. They found a correlation between the severity and duration of the hypoxia, and the cerebral symptoms. Since they regarded the role of the lung as cardinal, they attached great importance to arterial oxygen pressure. The maintained that the bone marrow was the source of the fat found in the lungs. The findings reported by Meek et al. (1972) also pointed in this direction. They demonstrated a marked increase in fat droplets in the femoral vein after fracture. The diameter of these droplets exceeded that of the lung capillaries. In their experimental set-up they were unable to demonstrate fat droplets in the systemic circulation.

In nearly all publications of recent date, correction of the arterial oxygen pressure is a central feature in the treatment of the clinical syndrome of fat embolism. This can be done by administration of oxygen, use of an oxygen tent, or controlled ventilation. Peltier (1969) advised controlled ventilation with the aid of fixed-volume respirators, believed to facilitate the flow of lymph in the lungs. The favourable effect of corticosteroids was reported by Ashbaugh et al. (1966). Linscheid and Dines (1969) advocated intravenous administration of alcohols. The German literature mentions a favourable effect of lipolytic

enzymes. The effect of heparin is controversial. Hardaway (1966) is a decided advocate, but Peltier (1969) doubted the effect of heparin.

It seems to be very important to ensure adequate fracture immobilization and rapid restoration of the circulation from the onset.

Analysis of the data on the patients in the present series posed the problem of which patients were to be classified as patients with fat embolism. Ultimately, patients who showed the clinical syndrome of fat embolism, with either petechiae or a very low pO_2, and those in whom the postmortem revealed fat in the lungs or elsewhere, were classified as such. By these criteria there were 37 patients with fat embolism, i.e. 11.2%. The diagnosis was based on petechiae in 21 cases, on the low pO_2 in 12 cases, and on postmortem findings in four cases. Fat embolism was studied in relation to:

* age
* sex
* season
* type of accident
* fracture type
* alcohol
* shock
* general associated injury
* local associated injury
* pelvic fracture
* homolateral lower leg fracture
* openness or closedness of fracture.

For the variable 'age' the expected numbers were too small to warrant conclusions, but the percentages seemed to suggest that no particular age group carried a higher risk of fat embolism. Significant differences in distribution were found for the variables sex, accident type, shock, general associated injury and homolateral lower leg fracture. No significant difference was demonstrable for the remaining variables. For the sake of brevity these data are not presented. Numerical data on the abovementioned significant relationships are presented in tables 99 through 103.

Table 99. Fat embolism in relation to sex.

	male		female	
no fat embolism	216	86%	70	96%
fat embolism	34	14%	3	4%

$\chi_{(1)}^2 = 4.12$. Significant ($p < 0.05$).

Table 100. Fat embolism in relation to accident groups.

	traffic		work		home	
no fat embolism	204	86%	30	97%	45	98%
fat embolism	33	14%	1	3%	1	2%

$\chi_{(2)}^2 = 7.54$. Significant ($p < 0.05$).

Table 101. Fat embolism in relation to shock.

	no shock		shock	
no fat embolism	215	91%	40	77%
fat embolism	22	9%	12	23%

$\chi_{(1)}^2 = 6.54$. Significant ($p < 0.02$).

Table 102. Fat embolism in relation to general associated injuries.

	no ass. injuries		ass. injuries	
no fat embolism	162	93%	124	83%
fat embolism	12	7%	25	17%

$\chi_{(1)}^2 = 6.78$. Significant ($p < 0.01$).

Table 103. Fat embolism in relation to homolateral lower leg fracture.

	no lower leg fracture		lower leg fracture	
no fat embolism	260	90%	26	74%
fat embolism	28	10%	9	26%

$\chi_{(1)}^2 = 6.37$. Significant ($p < 0.02$).

The impression was gained that it was in particular the serious accident victims that ran a risk of fat embolism.

In the present series two patients died as a direct result of fat embolism, and in five other cases fat embolism contributed to the fatal issue. The case histories of the deceased patients follow.

1. Patient nr. 008, a man aged 93, fell when he stepped off a curbstone and sustained a frac-

ture of the left femoral shaft. It was a closed oblique fracture at a proximal shaft level. Prior to the accident the patient had been in good general condition. The fracture was treated by means of a supracondylar wire extension. The general condition deteriorated, and on the third day after the accident the patient died showing symptoms of progressive pulmonary insufficiency. No arterial blood gas values were available. The postmortem showed massive fat embolism in the lungs.

2. Patient nr. 162, a man aged 91, was walking when he was hit by a car. He sustained an open transverse femoral shaft fracture with butterfly, open homolateral lower leg fracture, pelvic fracture, concussion of the brain and a head injury. The patient was in shock. After administration of blood, plasma and plasma substitutes, a wire extension was passed through the tibial tuberosity. Arterial blood gas values were good on the day after the accident, but in the course of that day the patient gradually became comatose. He died the next day. There were no petechiae. Fat was found in virtually all organs at the postmortem.

The data on fat embolism in the present series are probably not quite representative of the entire concept. One of the problems is that the diagnosis 'fat embolism' is insufficiently circumscribed. There is no diagnostic criterium on which the diagnosis can be based.

Analysis of the group of patients in the present series who showed 'fat embolism' diagnosed on the basis of different criteria, shows that patients in this group as a rule had had a serious traffic accident, that many of them had been in shock when admitted, and that there were many associated injuries.

The literature also gives the impression that it is these patients who run the risk of fat embolism.

In the present series the patients with fat embolism were treated by so many different methods that the data cannot be used in formulating a conclusion about the treatment of choice. However, the abovementioned general measures such as prevention, treatment and control of shock, and correction of the arterial oxygen pressure, are regarded as essential features in the prevention or treatment of fat embolism.

XII.8. SUMMARY

This chapter discussed the femoral shaft fracture in various combinations. The first combination discussed was that of femoral shaft fracture with a homolateral hip dislocation. This combination is rare, and the same applies to the combination of femoral shaft fracture with acetabular fracture. Nevertheless, it is occasionally encountered in patients who were seated in a car involved in an accident. The combination of femoral shaft fracture with homolateral femoral neck or pertrochanteric fracture was less uncommon: it occurred in 3.4% of cases in the present series. The causative accidents were mostly frontal car collisions, motorcycle or moped accidents or a fall from a great height. The femoral shaft fracture was an open fracture in 43%. Because the femoral shaft fracture masked the associated hip injury in a number of cases, the latter was not always recognized as such. Failure to diagnose such as hip injury can lead to serious disability. The importance of routine radiological examination of the pelvis in patients with a femoral shaft fracture is stressed.

The next combination discussed was that of femoral shaft fracture with an injury of the extensor apparatus. Rupture of the quadriceps tendon or of the patellar ligament was rare. The diagnosis again posed problems.

Combination with a homolateral patellar fracture was not uncommon. This combination endangers the function of the knee-joint. In the treatment of these combinations it seems important first to 'eliminate' the femoral shaft fracture by effecting an exercise-stable osteosynthesis.

Combination with a homolateral lower leg fracture was not rare; it was encountered in nearly 11% of patients in the present series. All these patients had been in accidents involving a car. The lower leg fracture was very often an open fracture (in 75% of cases in the present series). Both conservative and operative treatment of the femoral shaft fracture led to adequate recovery of knee function. It was proposed that in the treatment of this combination one of the fractures should always be 'eliminated' by means of an exercise-stable osteosynthesis. The fracture elimin-

ated should be that best suited to osteosynthesis or the fracture most in need of this due to the condition of adjacent soft tissues.

The next combination discussed was that with a nerve injury. Injury of the sciatic nerve is rare, but injury of the peroneal nerve is not. Loss of peroneal nerve function was diagnosed in 7.6% of patients in the present series. There are many possible causes, none of which seems predominant. It seems of importance in treatment to achieve an exercise-stable osteosynthesis of the fracture, thus creating the conditions for adequate treatment of the peripheral nerve injury.

The combination with injury of the superficial femoral artery is not common. Yet it is of importance to identify and treat this combination as such. A survey of the relevant literature shows that amputation was ultimately performed in the majority of cases. In the present series, three patients showed this combination. The diagnosis was promptly made, and reconstruction of the artery was successul in all these cases. This combination often involves a transverse femoral shaft fracture at a fairly distal shaft level.

A separate section of this chapter was devoted to fat embolism. Some definitions given in the literature were discussed. Difficulties encountered in diagnosis and therefore in analysis of clinical series were pointed out. The clinical syndrome of fat embolism was observed in about 11% of the patients in the present series. The diagnosis was based on petechiae or on low arterial oxygen pressure or on postmortem findings. The cardinal point in treatment seems to be the prevention or control of shock and registration and correction of the low arterial oxygen pressure.

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Chapter XIII
Summary and conclusions

In this thesis an attempt has been made to indicate the method of choice in the treatment of patients with a femoral shaft fracture.

In 1963 Dencker suggested on the basis of a detailed study of a large number of patients that routine treatment of patients with a femoral shaft fracture should be conservative treatment.

In the present study data are presented on 329 consecutive adult patients admitted to the Groningen University Clinic for primary treatment of a femoral shaft fracture. The period of observation ranged from 1st January 1958 through 31st December 1969. This period is about ten years later than the period covered in Dencker's study. New methods for the treatment of femoral shaft fractures have been evolved during these ten years. These new methods are Küntscher nail osteosynthesis *with* reaming of the medullary cavity, and A.O.-plate osteosynthesis.

In this study these two new methods are compared with conservative treatment and with Küntscher nail osteosynthesis *without* reaming of the medullary cavity.

A brief review of the history of femoral shaft fracture treatment is presented in Chapter I.

In Chapter II the femoral shaft is defined as that part of the femur that consists of compact bone. A description is given of a new method of marking the boundaries of the shaft on an anteroposterior radiograph.

Some aspects of the anatomy of the femur are discussed. A section is devoted to fracture mechanics, and the division into fracture types used in this study is motivated. Three groups of fracture types are distinguished: *bending fractures*, i.e. transverse fractures, oblique fractures, and transverse or oblique fractures with a triangular fragment known as butterfly; *comminuted fractures*, i.e. fractures which involve a large part of the shaft with several fragments of indeterminate shape; *torque fractures*, i.e. fractures with a spiral fracture plane, sometimes with a butterfly.

Chapter III describes the series of patients and the methods used in statistical analysis.

Chapter IV charts the femoral shaft fracture as it presented itself in the present study. A number of features emerge. A femoral shaft fracture shows the relatively highest frequency in young men and aged women. The frequency of femoral shaft fractures in men gradually decreases with increasing age, whereas in women it is precisely after age 50 that a marked increase in frequency occurs. The latter is probably due to the increased fragility of the bone as a result of osteoporosis under the influence of hormonal changes in the menopause.

Traffic accidents account for three-quarters of all femoral shaft fractures, the remaining fractures occurring in the work situation or in accidents at home. It is in particular the aged patients who are involved in the accidents at home.

A significant difference in left-sidedness or right-sidedness of femoral shaft fractures is observed between Dencker's series (Sweden) and the present series. The leg on the side of the oncoming traffic is more often involved than the leg on the side of the verge.

One out of every seven femoral shaft fractures is an open fracture.

General and local associated injuries are common in patients with a femoral shaft fracture. General associated injuries are seen in more than 50% of accident victims with a femoral shaft fracture and in as many as 77% of those seated in a car when the accident occurred. Accidents at home are rarely accompanied by general associated injuries.

Severe craniocerebral injury existed in 11.6% of patients in the present series. The majority were traffic accident victims.

Local associated injuries, i.e. injuries of the homolateral limb were observed in more than one-third of patients involved in a traffic accident or an indirect work accident.

The femoral shaft fracture was a transverse fracture in about one-third of cases, and a comminuted fracture in about one-fifth of cases. A comminuted fracture is most likely to occur after direct impingement of violence and in accidents involving a large amount of energy.

Torque fractures are found in particular in women involved in accidents at home. There is a significant relationship between torque fracture and pre-existent hip pathology.

The femoral shaft level immediately distal to the isthmus was found to be most frequently involved in a fracture.

Chapter V shows that the femoral shaft fractures in the present series were treated in four different ways:

* conservative treatment
* Küntscher nail osteosynthesis *without* reaming of the medullary cavity
* Küntscher nail osteosynthesis *with* reaming of the medullary cavity
* A.O.-plate osteosynthesis.

Four groups with the variable 'different method of treatment' were constituted.

About 10% of the patients were treated in a manner not classifiable under one of these four headings. This 'unclassifiable group' has been left undiscussed.

Efforts were made to establish whether there were significant differences in composition between the four groups. Significant differences were found for the variables 'fracture type' and 'shaft level involved'. They were caused by differences in indications for the various methods of treatment. These differences in composition between the groups are to be taken into account in the comparison of the groups. For a large number of other variables, no significant differences in composition between the groups were found.

The methods of treatment are compared on the basis of four aspects: duration of fracture union, rate and severity of complications, functional and anatomical results and socio-economic aspects.

Chapter VI presents data on mortality. The hospital mortality in the present series was 8.8%. With the exception of one, all patients who died under age 70 had had a severe craniocerebral injury. Deaths which occurred at age 70 and over were as a rule due to such complications as decubitus, urinary infection, bronchopneumonia or exacerbation of a pre-existent disease.

Of the patients who were 70 or older at the time of the accident, 33% died within six months.

Operative treatment as such caused no mortality in the sense of death on the operation-table or shortly after the operation. But osteosynthesis was by no means always able to prevent problems of the kind which occur in prolonged immobilization, e.g. decubitus and urinary infections. One of the problems was that the osteosynthesis did not always achieve the desired stability so that the patient had to remain immobilized nevertheless. The impression is that operative treatment of femoral shaft fractures in aged patients is recommendable, provided the osteosynthesis ensures exercise stability.

Chapter VII discusses the duration of fracture union. The moment of union was assessed on the basis of radiological findings. Eight months was accepted as normal duration of union. Union which occurred later was considered to be delayed union, while failure to achieve union was described as non-union or pseudarthrosis. In actual fact, non-union occurred in only one patient in this series.

Comparison of the various methods of treatment in terms of duration of union reveals Küntscher nail osteosynthesis *without* reaming of the medullary cavity to be a method associated with significantly slower union than conservative treatment and Küntscher nail osteosynthesis *with* reaming of the medullary cavity. The latter method of Küntscher nailing does not differ from conservative treatment in duration of union. A.O.-plate osteosynthesis lies in between the two methods of Küntscher nailing so far as duration of union is concerned.

It seems apparent from the findings in the present series that 'early' osteosynthesis of the femoral shaft fracture significantly increases the duration of union as compared with osteosynthesis carried out during the second, third or fourth week after the accident, and also as compared with conservative treatment.

No significant difference in duration of union was found between open and closed fractures. Union of comminuted fractures is perhaps somewhat slower than that of torque fractures.

Chapter VIII discusses the complications in the

treatment of the patients of the present series. The rate of general complications of the thromboembolic type was about the same with the various methods of treatment.

The present study confirms the statement found in the literature that infection of the fracture area is a very serious complication. Such a deep infection developed in 11 cases, and in all except one it occurred after operative treatment. Only two of these patients made a full recovery. Two other patients required an amputation, and in three deceased patients the infection was an important contributary to death. In this respect Küntscher nail osteosynthesis *with* reaming of the medullary cavity compares favourble with the other methods of operative treatment: no deep infection occurred in any of these patients.

The deep infections in turn gave rise to many other complications. In particular the duration of union was as a rule substantially increased as result. Refractures, too, were not uncommon. The majority of refractures, however, were observed in patients given conservative treatment (9.9%), and occurred between the tenth and the twelfth week. Immobilization for at least twelve weeks therefore seems indicated in conservative treatment.

Küntscher nail osteosynthesis was accompanied by a number of complications which are inherent to this technique. For example, bending or breaking of the nail was not uncommon after Küntscher nail osteosynthesis *without* reaming of the medullary cavity, using a Küntscher nail of small diameter. This was no longer observed with nails of larger diameter, as used after reaming of the medullary cavity. With the latter method, jamming of the nail also became an exception. In a few cases, however, the bone split while the nail was being driven in. As a rule this meant that the desired exercise stability was not achieved.

The site of predilection for application of an extension wire in conservative treatment was found to be the tibial tuberosity.

The number and severity of complications after wiring at this site were limited.

Comparison of the rates of complications for the four methods of treatment shows that Küntscher nail osteosynthesis *with* reaming of the medullary cavity and conservative treatment are relatively safe methods.

Chapter IX discusses the methods used in the follow-up study. At the time of the follow-up, 265 patients were still alive, and all were traced. The author personally examined 251 of the patients (95%) at the out-patient clinic. On the 14 patients not personally examined, a sufficient body of information was available to warrant the statement that this group entails no selection and that the results of the follow-up study are not influenced by elimination of these 14 patients.

The results of the follow-up study are presented in chapters X and XI.

Chapter X discusses the anatomical and functional results. The anatomical results were divided into differences in length, angular deformities and rotation deformities.

The difference in length showed a significant difference in distribution over the methods of treatment. About 50% of patients given conservative treatment showed shortening. In the patients treated by Küntscher nail osteosynthesis the rate of shortening was about 20%. Shortening was rarely observed in patients treated by A.O.-plate osteosynthesis. An analysis of the patients with shortening shows that the degree of shortening after Küntscher nail osteosynthesis *with* reaming of the medullary cavity and after A.O.-plate osteosynthesis did not exceed 2 cm. The patient as a rule was not inconvenienced by any shortening up to 2 cm.

Shortening exceeding 2 cm was observed in a few cases of conservatively treated comminuted fractures and in complications following Küntscher nail osteosynthesis *without* reaming of the medullary cavity.

Angular deformities in the frontal plane (varus and valgus deformities) were most common in the 'conservative treatment' group: 41% of cases. Their frequency in operatively treated patients was significantly lower.

A varus deformity of 15° or more was found in six patients after conservative treatment and in three after Küntscher nail osteosynthesis *without* reaming of the medullary cavity. These nine patients with a severe varus deformity were not inconvenienced by symptoms arising from the knee-joint. The literature indicates that in particular varus deformities are a menace to the knee-joint, but the data on the present series do not confirm this. It is to be noted, however, that the period of observation may have been too short to warrant definite conclusions in the respect.

Angular deformities in the sagittal plane (antecurvation and recurvation) show significant differ-

ences in distribution over the various methods of treatment. A deformity of this type was rarely observed after A.O.-plate osteosynthesis, and only after a complication.

Some slight recurvation was not uncommon after Küntscher nail osteosynthesis. This arises from the fact that a Küntscher nail often neutralizes the physiological antecurvation of the femur. After Küntscher nail osteosynthesis *without* reaming of the medullary cavity, a few patients showed severe antecurvation which was always attributable to complications.

Angular deformities in the sagittal plane were observed in 40% of conservatively treated patients. In the majority the deformity was small. But a few patients showed an antecurvation or recurvation of 15° or more. They were not inconvenienced by the deformity.

As compared with the literature, the present series showed a conspicuously high rate of rotation deformities. In this respect too there were significant differences in the distribution over the methods of treatment. And again A.O.-plate osteosynthesis compares very favourably with the other methods: slight rotation deformity in only 12% of cases. The rotation deformity rate in the conservatively treated patients was 37%; most of these rotation deformities were limited to 10–20°.

After Küntscher nail osteosynthesis *without* or *with* reaming of the medullary cavity, nearly 50% of patients showed a rotation deformity! Exorotation was more common than endorotation. Two causes of the high frequency of this deformity are outlined.

It was found in the present series that patients with 20° exorotation or more can be inconvenienced as a result. The inconvenience is that the knee and leg, and sometimes the hip, tire more readily upon effort than their counterparts on the intact side.

No radiological evidence of osteoarthritis of the knee-joint or hip-joint was found in patients with 20, 30 or 40° exorotation. But one patient with 50° exorotation did show degenerative changes in the knee-joint, accompanied by symptoms.

Functional results were assessed on the basis of recovery of knee function. No use was made of data on the difference in circumference between the affected and the unaffected leg (so-called quadriceps atrophy): the comparison proved to be subject to the influence of too many different factors.

The distribution of patients with and without limitation of movement in the knee-joint differed significantly with different methods of treatment. The rate of limitation of movement was low after osteosynthesis with stability, e.g. Küntscher nail osteosynthesis *with* reaming of the medullary cavity, and A.O.-plate osteosynthesis; and such limitation of movement as did occur did not exceed a maximum of 30°.

After Küntscher nail osteosynthesis *without* reaming of the medullary cavity, limitation of movement in the knee-joint occurred in some 25% of patients. Although in the majority of these patients the limitation was only 10–30°, a few patients showed 50–60° limitation of movement; one patient had a virtually ankylotic knee-joint following deep infection.

Limitation of movement was most common in the group of conservatively treated patients, some 50% of whom showed a degree of limitation of 10–20° (with a maximum of 40°.)

It can be concluded with some reservation that comminuted fractures more frequently lead to limitation of movement in the knee-joint than do bending or torque fractures. An explanation is sought in the more extensive soft-tissue injuries associated with comminuted fractures.

Comparison of anatomical and functional results in relation to the various methods of treatment revealed that slight shortening and slight angular deformity frequently remained after conservative treatment, but rarely produced symptoms. After nonexercise-stable osteosynthesis, e.g. Küntscher nail osteosynthesis *without* reaming of the medullary cavity, marked anatomical deformities were observed in a number of cases, particularly after complications. After Küntscher nail osteosynthesis *with* reaming of the medullary cavity it was actually only rotation deformities that marred the result. A.O.-plate osteosynthesis proved to offer an almost complete guarantee for maintenance of anatomical reduction.

In terms of functional recovery, Küntscher nail osteosynthesis *with* reaming of the medullary cavity and A.O.-plate osteosynthesis both gave excellent results. The conservatively treated patients included a fair number in whom slight limitation of movement resulted, which did not inconvenience these patients.

Chapter XI deals with a number of socio-

economic aspects. In the present series the mean duration of the period in hospital proved to be 53.48 days. In this calculation, patients in whom associated injuries were of influence were excluded. There was a significant difference in hospital period between the conservatively treated group and the three groups of patients given operative treatment.

The hospital period for the conservatively treated patients averaged 80 days; the period for Küntscher nail osteosynthesis was 38 days *without* and 30 days *with* reaming of the medullary cavity; for A.O.-plate osteosynthesis a mean hospital period of almost 60 days was calculated. This relatively long hospital period is probably due to the fact that three patients in this category spent a very long time in hospital for treatment of a deep infection.

The mean duration of unfitness to work was 9.17 months in the relevant patients of this series. The mean duration of unfitness to work after Küntscher nail osteosynthesis *with* reaming of the medullary cavity was two months shorter than that following the other methods. Permanent disability due to the femoral shaft fracture was fairly exceptional; it was more often due to sequelae of associated injuries or conditions unrelated to the accident.

Chapter XII considers the femoral shaft fracture in various combinations. It discusses femoral shaft fracture combined with a homolateral hip injury, with special reference to a homolateral medial femoral neck fracture or pertrochanteric fracture. This proximal fracture is not infrequently overlooked. The same can be the case with a femoral shaft fracture in combination with an injury of the extensor apparatus. Combination of a femoral shaft fracture with a homolateral lower leg fracture is not uncommon. In the present series this combination was found in 11% of patients. All these patients had been in accidents involving a car. The lower leg fracture was an open fracture in 75% of these cases.

It was found to be important to reduce the problems with the management of both fractures by 'eliminating' one of the fractures by means of an exercise-stable osteosynthesis.

Femoral shaft fracture with a lesion of the sciatic nerve is a fairly rare but serious combination. Loss of peroneal nerve function is more frequently observed. This loss of function can have many causes, none of which stands out especially.

A relatively rare combination is that of femoral shaft fracture and an injury of the superficial femoral artery (1%). But the consequences of non-recognition or inadequate treatment of the vascular lesion in such combinations are very serious: as a rule this leads to an amputation. In the three patients who showed this combination in the present series, reconstruction of the artery was always successful. At the same time fixation of the femoral shaft fracture was effected. In each of these three cases the leg was saved.

A separate section is devoted to fat embolism, which is not uncommon in patients with a femoral shaft fracture. Difficulties are encountered in an attempt to give an exact definition of the term 'fat embolism'. Consequently it is difficult to compare clinical studies.

In the present series the diagnosis 'fat embolism' was made on the basis of three different criteria: clinical syndrome with petechiae, very low arterial oxygen pressure and postmortem evidence of fat droplets in the lungs or elsewhere. On the basis of these criteria, fat embolism was diagnosed in about 11% of the patients in the present series. Most of them had been in a serious traffic accident, as a rule had many associated injuries, and had been admitted in shock. The cardinal features of treatment are the prevention or control of shock and the registration and correction of the abnormally low arterial oxygen pressure.

The question which arises at the conclusion of this study is: 'What is the treatment of choice for a patient with a femoral shaft fracture?'. Thus phrased, this question cannot be answered, for a patient with a femoral shaft fracture presents so wide a variety of pathology that there can be no question of any particular treatment of choice.

It seems best to divide patients with a femoral shaft fracture into those who had an accident in traffic or in the work situation, and those who had an accident at home. The latter group includes mostly aged individuals, as a rule female, with a closed femoral shaft fracture as sole injury.

Emphasis in treatment should be primarily on the general condition and on pre-existent diseases, if any. Treatment should be conservative to begin with. When after a few days it is established that there are no contraindications to operation,

and when stable fixation of the fracture seems feasible, operative treatment of the fracture is indicated. But only if true exercise stability can be achieved does operative treatment seems to offer advantages. In the postoperative phase, prevention of bronchopneumonia, decubitus and urinary infections should receive attention. Of course these general measurements also applie in conservative treatment.

By observing the rules outlined above it may be possible to reduce the large percentage of deaths within six months of the accident which occur among aged patients (33% in the present series).

The groups 'traffic accidents' and 'work accidents' show a male predominance. In these patients, and particularly in the traffic accident victims, general associated injuries often take priority.

In such cases the initial treatment of the femoral shaft fracture is as a rule conservative, with the exception of patients in whom there is an absolute indication to operative intervention. This will be discussed later.

It is essential that initial conservative treatment be optimal from the start. It is an error to accept an angular deformity or substantial shortening with the intention to correct it at subsequent osteosynthesis. For with patients in this category one never knows which problems and which absolute contraindications to osteosynthesis may present themselves.

In the groups 'traffic' and 'work', in which general associated injuries are not predominant, it is necessary to identify those patients in whom there is an absolute indication for osteosynthesis of the femoral shaft fracture. These are patients with a femoral shaft fracture in combination with:

1. homolateral hip dislocation
2. injury of the superficial femoral artery
3. injury of the sciatic nerve
4. injury of the extensor apparatus of the knee
5. severe homolateral knee injury
6. very extensive soft-tissue injury (e.g. devitalized muscle tissue, large skin defects etc.)

In these cases there is an indication for immediate operative intervention, regardless of whether the fracture is open or closed. As a rule, A.O.-plate osteosynthesis will be preferred in these cases because this procedure nearly always ensures exercise stability, regardless of fracture type.

The risk of delayed union in these cases is outweighed by the favourable conditions which are created for optimal anatomical and functional recovery.

The absolute indication mentioned sub. 6 may seem somewhat controversial. After all, the operation increases the trauma to the soft tissues and by that the amount of devitalized tissue. With these injuries, however, the situation is different. If uneventful healing of the accident wound is to be ensured, then fracture stabilization is to be regarded as a component of the extensive wound toilet (which may, for example, encompass skin grafts).

Only in this way optimal healing of soft tissues can be ensured. The remaining muscle groups can be exercised in an early stage, thus minimizing the damage inflicted by the accident.

This study suggests that conservative treatment is the initial treatment of choice for all other patients with a femoral shaft fracture. If operating-room facilities are excellent with regard to asepsis, anaesthesia and staff, an exception can be made for closed fractures combined with a homolateral hip fracture, a femoral neck fracture, a homolateral patellar fracture or a homolateral lower leg fracture. Only if strict criteria for safe osteosynthesis can be fulfilled osteosynthesis à chaud for the abovementioned relative indications is justified.

In principle, however, and certainly in dealing with open fractures, conservative treatment is to be initially preferred. But, again, this conservative initial treatment should aim from the start at optimal reduction of the fracture fragments. At any suspicion of interposition or in the event of a persistent angular deformity, an attempt at reduction under general anaesthesia should be made.

In the course of the second week after the accident, patients suitable for elective osteosynthesis should be selected. At that time the pathophysiological processes started by the accident are in regression, and the threat of fat embolism is virtually a matter of the past. During this period the art lies in selecting those patients who can benefit from operative treatment of their femoral shaft fracture.

Does this mean that conservative treatment is less good?

Although conservative treatment is a safe treatment, which as a rule gives a fair, satisfactory result, it requires a very long period in hospital. Today osteosynthesis techniques are available

which can significantly shorten the hospital period and which offer a better guarantee of complete anatomical and functional recovery than conservative treatment.

The patients to be selected are those with bending fractures suitable for exercise-stable fixation, preferably by Küntscher nail osteosynthesis *with* reaming of the medullary cavity.

The results of this technique proved to be excellent in the present series, even though too large a percentage of rotation deformities occurred. These, however, can be ascribed to the closed reduction technique used, and it seems possible to prevent them by using open reduction.

Küntscher nail osteosynthesis *without* reaming of the medullary cavity should no longer be used as routine procedure. Its indications are too limited (specifically: transverse fractures precisely in the isthmus) and its complications are numerous, at least in the present series.

A.O.-plate osteosynthesis has a wider range of indications than Küntscher nail osteosynthesis with reaming of the medullary cavity. This technique can be used to achieve exercise stability of comminuted fractures, bending fractures with a large butterfly, and torque fractures. It ensures virtually complete anatomical and functional recovery, unless deep infection ensues. The consequences of such a deep infection are very serious even if adequate treatment is given. However, if the frequency of such deep infections is considerably reduced, in that situation the technique of osteosynthesis with the A.O.-compression plate is decidedly an important asset.

In 1963 Dencker reached the conclusion that: 'Conservative treatment is the method of choice in routine treatment of femoral shaft fratures'. Should this conclusion be revised in 1973?

This question is to be answered in the affirmative. Küntscher nail osteosynthesis *with* reaming of the medullary cavity and, with some reservation, A.O.-plate osteosynthesis are newly available techniques which, if optimally executed, ensure an unmistakable gain for the majority of patients with a femoral shaft fracture.

Chapter XIV
Samenvatting en conclusies

De onderhavige studie wil trachten aan te geven welke de beste methode van behandeling is van een patient met een femurschachtfractuur.

Er is een uitspraak van Dencker uit 1963, gebaseerd op een gedegen studie van een groot aantal patienten. Dencker's conclusie is, dat de conservatieve behandeling de beste routinebehandeling voor een femurschachtfractuur is.

In deze studie worden de gegevens medegedeeld van 329 opeenvolgende, volwassen patienten, die allen voor eerste behandeling van een femurschachtfractuur in de Groningse Universiteitskliniek zijn opgenomen. De observatieperiode loopt van 1 januari 1958 tot en met 31 december 1969. Deze periode ligt ongeveer tien jaar later dan de periode, die de studie van Dencker bestrijkt. In deze tien jaren zijn nieuwe behandelingsmethoden voor de femurschachtfractuur tot ontwikkeling gekomen. Het betreft de Küntscherpenosteosynthese *met* opboren van de mergholte en de AO-compressieplaat.

In deze studie worden deze twee nieuwe methoden vergeleken met de conservatieve behandelingsmethode en met de Küntscherpenosteosynthese *zonder* opboren van de mergholte.

In hoofdstuk I wordt een overzicht gegeven van de historie van de behandeling van femurschachtfracturen.

In hoofdstuk II wordt een definitie van de femurschacht gegeven. Het uit compact bot opgebouwde gedeelte wordt als zodanig benoemd. Een nieuwe methode om de schacht op een voorachterwaartse röntgenfoto te begrenzen, wordt beschreven.

Enkele aspecten van de anatomie van het dijbeen worden behandeld. Er wordt een paragraaf gewijd aan de fractuurmechanica, waarin een motivatie wordt gegeven voor de in deze studie gemaakte indeling in fractuurtypen. Drie groepen fractuurtypen worden onderscheiden: *buigingsbreuken*: dit zijn dwarse, schuine en dwarse of schuine breuken met een driehoekig fragment, *comminutieve breuken*: dit zijn breuken, waarbij een groter deel van de schacht is betrokken met meerdere fractuurstukken zonder duidelijke vorm en *torsiebreuken*: waarbij het verloop van het breukvlak spiraalvormig is, soms met een driehoekig fragment gepaard gaande.

In hoofdstuk III wordt het patientenbestand en de methode van statistisch onderzoek beschreven.

In hoofdstuk IV wordt de femurschachtfractuur, zoals deze zich in de onderhavige studie voordeed, in kaart gebracht. Enkele punten komen naar voren. Zo is er een significant verschil met betrekking tot de verdeling over de geslachten. Een femurschachtfractuur komt bij jonge mannen en bejaarde vrouwen relatief het vaakst voor. Het voorkomen van de femurschachtfractuur bij mannen neemt geleidelijk af met het ouder worden, terwijl bij vrouwen juist na het vijftigste jaar een sterke stijging in het voorkomen optreedt. Dit laatste is waarschijnlijk het gevolg van grotere breekbaarheid van het bot ten gevolge van osteoporose onder invloed van hormonale varanderingen in de menopauze.

Verkeersongevallen zijn verantwoordelijk voor driekwart van de femurschachtfracturen, terwijl de resterende fracturen in een werksituatie of door ongevallen thuis ontstaan. Bij ongevallen thuis zijn het vooral de bejaarde patienten, die worden getroffen.

Er wordt een significant verschil in het links of rechts voorkomen van femurschachtfracturen gevonden tussen de serie van Dencker (Zweden) en de onderhavige serie. Het been aan de zijde van het tegemoetkomende verkeer wordt vaker getroffen dan het been aan de zijde van de berm. Globaal genomen is één van de zeven femurschachtfracturen een open fractuur.

Algemene en locale nevenletsels komen bij patienten met een femurschachtfractuur vaak voor. Bij verkeersongevallen heeft meer dan de helft van de patienten een algemeen nevenletsel, bij inzittenden van een auto is het percentage zelfs 77%. Een ongeluk thuis gaat zelden met een algemeen nevenletsel gepaard.

Een ernstig schedelletsel kwam in de onderhavige serie bij 11,6% van de patienten voor. Het betrof hoofdzakelijk verkeersslachtoffers. Locale nevenletsels, i.e. letsels aan hetzelfde been, zijn bij ruim éénderde van de patienten met een verkeersongeval of een indirect werkongeval waargenomen.

In ongeveer éénderde van de gevallen is de femurschachtfractuur een dwarse fractuur, in éénvijfde van de gevallen een comminutieve fractuur. Een comminutieve fractuur ontstaat vooral bij een direct letsel en bij ongevallen die gepaard gaan met hoge energie. Torsiefracturen worden vooral gezien bij vrouwen, die een ongeval thuis krijgen. Er is een significante relatie tussen het optreden van een torsiefractuur en het hebben van een prae-existente heuppathologie. Het blijkt, dat dat deel van de femurschacht dat juist onder de isthmus is gelegen, het vaakst bij een fractuur is betrokken.

In hoofdstuk V komt naar voren, dat de femurschachtfracturen van de onderhavige serie op vier manieren zijn behandeld:

* conservatieve behandeling,
* de Küntscherpenosteosynthese *zonder* opboren van de mergholte,
* de Küntscherpenosteosynthese *met* opboren van de mergholte,
* de AO-plaatosteosynthese.

Ongeveer 10% van de patienten is behandeld op een wijze, die niet past in één van de vier groepen. Deze patienten zijn geplaatst in een groep 'niet indeelbaar', en worden verder buiten beschouwing gelaten.

Vier groepen met als variabele 'verschillende behandelingsmethode' zijn gevormd.

Er is nagegaan in hoeverre er significante verschillen zijn in de samenstelling van de vier groepen. Met betrekking tot de variabelen 'fractuurtype' en 'plaats van de fractuur in de schacht', zijn er significante verschillen. Deze worden veroorzaakt door verschillen in het indicatiegebied van de respectievelijke behandelingsmethoden. Bij de beoordeling van de vergelijking dient rekening te worden gehouden met deze verschillen in samenstelling van de groepen. Voor een groot aantal andere variabelen blijken er geen significante verschillen in samenstelling van de vier groepen te bestaan.

De behandelingsmethoden worden vergeleken met betrekking tot vier aspecten: de duur van de consolidatie, de aantallen en de ernst van de complicaties, de functionele en de anatomische resultaten en enkele sociaal-economische aspecten.

In hoofdstuk VI worden de gegevens met betrekking tot de mortaliteit medegedeeld. De ziekenhuismortalitiet in de onderhavige serie bedraagt 8,8%. De overleden patienten onder de 70 jaar hadden, met één uitzondering, als nevenletsel een ernstig schedel-hersenletsel. Patienten van 70 jaar en ouder, die overleden, kregen in de regel een complicatie, zoals decubitus, urinewegінfectie, bronchopneumonie of een verergering van een prae-existente ziekte. Van de patienten, die ten tijde van het ongeval 70 jaar of ouder waren, overleed 33% binnen een half jaar na het ongeval.

Operatiemortalitieit in de zin van overlijden op de operatietafel of direct na de operatie deed zich bij de operatief behandelde patienten niet voor. Problemen, zoals die zich voordoen bij langdurige immobilisatie, i.e. decubitus en urineweginfecties, konden lang niet altijd door een osteosynthese worden voorkomen. Eén van de problemen was, dat de osteosynthese niet steeds de gewenste stabiliteit bood, waardoor de patient na de operatie toch geïmmobiliseerd moest blijven. De indruk bestaat, dat operatieve behandeling van de femurschachtfractuur bij bejaarde patienten aanbeveling verdient, mits er bij de osteosynthese oefenstabiliteit kan worden bereikt.

In hoofdstuk VII wordt de duur van de consolidatie behandeld. Enkele aspecten van fractuurgenezing worden genoemd. Er is gekozen voor een beoordeling van het moment van consolidatie aan de hand van het röntgenologische beeld. Als termijn van een normale consolidatie wordt acht maanden aangehouden. Treedt consolidatie later op, dan wordt van vertraagde consolidatie gesproken, terwijl bij uitblijven van consolidatie van non-union of pseudarthrose wordt gesproken. Dit laatste deed zich in feite in de onderhavige serie slechts bij één patient voor. Bij de vergelijking van de verschillende behandelingsmethoden met betrekking tot de consolidatieduur blijkt de Küntscherpenosteosynthese *zonder* op-

boren van de mergholte een methode te zijn, die gepaard gaat met een significant tragere consolidatie dan de conservatieve behandelingsmethode en de methode, waarbij de mergholte wel wordt opgeboord.

Deze laatste methode verschilt in consolidatieduur niet met die van de conservatieve behandelingsmethode. De osteosynthese met de AO-plaat ligt qua consolidatieduur tussen de beide Küntscherpenosteosynthese methoden in.

Uit de onderhavige studie komt naar voren, dat het à chaud verrichten van een osteosynthese van een femurschachtfractuur gepaard gaat met een significante verlenging van de consolidatieduur in vergelijking met een osteosynthese in de tweede, derde of vierde week na het ongeval, dan wel in vergelijking met de duur bij conservatieve behandeling. Tussen open en gesloten fracturen is geen significant verschil in consolidatieduur gevonden. Mogelijk consolideren comminutieve fracturen trager dan torsiefracturen.

In hoofdstuk VIII worden de complicaties bij de behandeling van de patienten van de onderhavige serie besproken. Algemene complicaties in de zin van thrombo-embolische complicaties traden bij de verschillende behandelingsmethoden ongeveer even vaak op.

Zoals uit de litteratuur reeds bekend is, blijkt ook uit de onderhavige studie, dat een diepe infectie van het fractuurgebied een zeer ernstige complicatie is. Elf keer deed zich zo'n diepe infectie voor, op één na steeds na operatieve behandeling. Een goed herstel trad slechts bij twee patienten op. Bij twee andere patienten was een amputatie nodig en bij drie overleden patienten heeft de infectie in belangrijke mate bijgedragen tot dit overlijden. De groep patienten, behandeld met een Küntscherpenosteosynthese *met* opboren van de mergholte, komt in dit opzicht gunstig naar voren: er deed zich bij deze patienten geen diepe infectie voor. Ernstige infecties traden op in aansluiting aan de Küntscherpenosteosynthese *zonder* opboren van de mergholte en de AO-plaatosteosynthese. Deze diepe infecties hadden op hun beurt weer vele andere complicaties tot gevolg. Met name werd de duur van de consolidatie in de regel aanzienlijk verlengd. Ook traden refracturen nogal eens op. De meeste refracturen werden echter waargenomen bij patienten, die conservatief werden behandeld (9,9%) en dan vooral in de periode tussen de tiende en de twaalfde week. Een immobilisatieduur van tenminste twaalf weken lijkt bij conservatieve behandeling dan ook aangewezen.

De Küntscherpenosteosynthese ging gepaard met een aantal complicaties, die inherent zijn aan de techniek. Zo werd bij de Küntscherpenosteosynthese *zonder* opboren van de mergholte, waarbij Küntscherpennen met een geringe diameter werden gebruikt, nogal eens buigen of breken van de pen waargenomen. Dit deed zich bij pennen van een grotere diameter, zoals die gebruikt werden in aansluiting aan het opboren van de mergholte, niet meer voor. Ook het vastlopen van de pen behoorde bij deze laatste methode tot de uitzonderingen. Wel werd een enkele keer waargenomen, dat het bot tijdens het inslaan van de pen spleet. Dit betekende in de regel dat de gewenste oefenstabilitieit niet werd bereikt.

De voorkeursplaats voor de extensiedraad bij de conservatieve behandeling bleek de tuberositas tibiae te zijn. Het aantal en de ernst van de complicaties van een draad, aangebracht op deze plaats, waren gering.

Bij vergelijking van het voorkomen van complicaties bij de vier behandelingsmethoden komt naar voren, dat de Küntscherpenosteosynthese *met* opboren van de mergholte en de conservatieve behandelingsmethode relatief veilige methoden zijn.

In hoofdstuk IX wordt de methodiek van het na-onderzoek behandeld. Ten tijde van het na-onderzoek waren 265 patienten in leven, die allen konden worden opgespoord. 251 patienten, i.e. 95%, werden door de schrijver poliklinisch onderzocht. Van de 14 patienten, die niet persoonlijk konden worden onderzocht, staat voldoende informatie ter beschikking om te mogen stellen, dat deze groep geen selectie inhoudt en dat de uitkomsten van het na-onderzoek niet worden beïnvloed door het ontbreken van deze 14 patienten.

Het gemiddeld interval tussen ongeval en na-onderzoek bedraagt 4½ jaar met als uitersten 2 jaar en 14½ jaar.

De gegevens van het na-onderzoek zijn neergelegd in de hoofdstukken X en XI. Hoofdstuk X behandelt de anatomische en functionele resultaten. De anatomische resultaten zijn onderverdeeld in lengteverschillen, asafwijkingen en rotatiefouten. Het voorkomen van een lengteverschil toonde een significant verschil in de verdeling over de behandelingsmethoden. Bij de helft van de conservatief behandelde patienten was er sprake van een verkorting.

Bij de met een Küntscherpenosteosynthese behandelde patienten kwam een verkorting in ongeveer 20% van de gevallen voor. Bij de patienten met een AO-plaatosteosynthese was zelden sprake van een verkorting.

Een analyse van de patienten met een verkorting leert, dat de hoeveelheid verkorting bij de Küntscherpenosteosynthese *met* opboren van de mergholte en de AO-plaatosteosynthese ten hoogste 2 cm bedroeg. Zo'n verkorting van 2 cm werd door de patient in de regel niet als hinderlijk ondervonden.

Enkele gevallen van een verkorting van meer dan 2 cm deden zich voor bij conservatief behandelde comminutieve fracturen en bij complicaties van de Küntscherpenosteosynthese *zonder* opboren van de mergholte.

Asafwijkingen in het frontale vlak, in casu varus en valgus, deden zich het vaakst voor bij de groep 'conservatief behandelde patienten', in een percentage van 41%. Bij de operatief behandelde patienten kwam zo'n asafwijking significant minder vaak voor.

Er waren zes patienten met een varusstand van 15° of meer na conservatieve behandeling en drie na een Küntscherpenosteosynthese *zonder* opboren van de mergholte. Deze negen patienten met een ernstige varusstand hadden geen bezwaren van het kniegewricht. In de litteratuur wordt aangegeven, dat met name varusafwijkingen een bedreiging betekenen voor het kniegewricht. De gegevens van de onderhavige serie onderschrijven dit niet. Er moet echter op worden gewezen, dat met betrekking tot dit aspect de observatieperiode mogelijk te kort is.

Asafwijkingen in het sagittale vlak, in casu antecurvatie en recurvatie tonen significante verschillen in de verdeling over de behandelingsvormen. Bij de AO-plaatosteosynthese trad zelden zo'n asafwijking op en dan nog uitsluitend na een complicatie.

Na een Küntscherpenosteosynthese betrof de asafwijking nogal eens een geringe recurvatie. Dit komt voort uit het gegeven, dat een Küntscherpen de fysiologische antecurvatie van het femur vaak opheft. Bij de Küntscherpenosteosynthese *zonder* opboren van de mergholte traden enkele gevallen van ernstige antecurvatie op, die steeds waren terug te voeren op complicaties. Onder de conservatief behandelde patienten werd een percentage asafwijkingen in het sagittale vlak van 40% gevonden.

Meestal was de asafwijking gering. Toch waren er enkele patienten met een ante- of een recurvatie van 15° of meer. Klachten hiervan werden niet aangegeven.

Rotatiefouten deden zich in de onderhavige studie in vergelijking met die uit de litteratuur opmerkelijk vaak voor. Ook ten aanzien van dit aspect toonde de verdeling over de behandelingsvormen een significant verschil. De AO-plaatosteosynthese komt wederom zeer goed naar voren: slechts 12% rotatiefouten en dan nog slechts geringe. Bij de conservatief behandelde fracturen bedroeg het percentage rotatiefouten 37%. Het betrof hier meestal slechts een rotatiefout van 10° of 20°. Bij de Küntscherpenosteosynthese zowel *met* als *zonder* opboren van de mergholte werd in bijna de helft van de gevallen een rotatiefout vastgesteld! Het betrof hier vaker een exorotatiefout dan een endorotatiefout. Twee oorzaken voor het frequent voorkomen van deze fout worden aangegeven. Het bleek uit de onderhavige studie, dat de patienten met een rotatiefout van 20° of meer hiervan klachten kunnen ondervinden. De klachten zijn, dat het been en de knie en soms ook de heup bij inspanning eerder moe zijn dan de gezonde zijde.

Röntgenologische aanwijzingen voor een arthrosis deformans van het knie- of heupgewricht werden bij de patienten met 20, 30 of 40° exorotatie niet waargenomen. Eén patient met 50° exorotatie heeft wel degeneratieve afwijkingen aan het kniegewricht, die met klachten gepaard gaan.

Het functionele herstel is nagegaan aan de hand van het herstel van de kniefunctie. Geen gebruik werd gemaakt van de gegevens met betrekking tot het verschil in omvang van het aangedane en het gezonde been, de zogenaamde 'quadricepsatrofie'. Er bleken teveel factoren te zijn, die deze vergelijking beïnvloeden.

De verdeling van de patienten met en zonder kniefunctiebeperking toont een significant verschil in de verdeling over de behandelingsvormen. Bij de stabiele osteosynthesevormen, zoals de Küntscherpenosteosynthese *met* opboren van de mergholte en de AO-plaatosteosynthese was het aantal patienten met een kniefunctiebeperking gering, terwijl een eventuele functiebeperking beperkt bleef tot ten hoogste 30° flexiebeperking.

Bij de Küntscherpenosteosynthese *zonder* opboren van de mergholte kwam een kniefunctiebeperking onder de na-onderzochte patienten in

ongeveer 25% voor. Hoewel bij het merendeel van de patienten de kniefunctiebeperking slechts 10 tot 30° bedroeg, zijn er toch enkele patienten met 50 tot 60° functiebeperking, terwijl er één patient is met een vrijwel ankylotisch kniegewricht in aansluiting aan een diepe infectie. De meeste patienten met een kniefunctiebeperking werden gevonden in de groep patienten, die conservatief waren behandeld. Ruim 50% van deze patienten had een kniefunctiebeperking, die in het merendeel van de gevallen slechts 10 tot 20° en maximaal 40° bedroeg.

Onder voorbehoud kan worden gesteld, dat bij comminutieve fracturen vaker een kniefunctiebeperking resteert, dan bij buigings- of torsiefracturen. Als oorzaak wordt het grotere weke delen letsel bij comminutieve fracturen genoemd.

Bij vergelijking van de anatomische en functionele resultaten met betrekking tot de verschillende behandelingsmethoden komt naar voren dat bij conservatieve behandeling een geringe verkorting en een geringe asafwijking frequent voorkwamen. Zelden waren deze klachtengevend. Bij de niet stabiele osteosynthesetechniek, zoals de Küntscherpenosteosynthese *zonder* opboren van de mergholte, werden in een aantal gevallen en dan vooral na complicaties ernstige anatomische afwijkingen waargenomen. Bij de Küntscherpenosteosynthese *met* opboren van de mergholte waren het eigenlijk alleen de rotatiefouten, die stoorden. De AO-plaatosteosynthese bleek vrijwel volledige garantie te bieden voor het behoud van een anatomische repositie. Ten aanzien van het functionele herstel toonde de Küntscherpenosteosynthese *met* opboren van de mergholte en de AO-plaatosteosynthese voortreffelijke resultaten. Bij de conservatief behandelde groep is er een vrij groot percentage patienten, waarbij een lichte functiebeperking resteert, die echter door de patient niet als hinderlijk wordt ondervonden.

In hoofdstuk XI worden enkele sociaal-economische aspecten belicht. De gemiddelde opnameduur in de onderhavige serie blijkt 53,48 dagen te bedragen. Bij deze berekening zijn de patienten, bij wie er een invloed was van nevenletsels, niet meegeteld.

Er is een significant verschil in opnameduur tussen de conservatief behandelde groep en de drie operatief behandelde groepen patienten. Bij de conservatief behandelde patienten bedraagt de gemiddelde opnameduur 80 dagen, bij de Küntscherpenosteosynthese *zonder* en *met* opboren van de mergholte respectievelijk 38 en 30 dagen, terwijl voor de AO-plaatosteosynthese een gemiddelde opnameduur van bijna 60 dagen werd berekend. Deze relatief lange opnameduur bij de AO-plaatosteosynthese wordt waarschijnlijk veroorzaakt door drie patienten, die langdurig in de kliniek zijn verpleegd vanwege een diepe infectie.

De gemiddelde duur van de arbeidsongeschiktheid van de daarvoor in aanmerking komende patienten bedraagt in deze serie 9,17 maanden. De Küntscherpenosteosynthese *met* opboren van de mergholte heeft een gemiddelde duur van de arbeidsongeschiktheid, die twee maanden korter is dan de overige methoden. Een blijvende arbeidsongeschiktheid ten gevolge van een femurschachtfractuur bleek een vrij uitzonderlijke zaak te zijn.

Vaker was zo'n blijvende arbeidsongeschiktheid gebaseerd op resttoestanden van nevenletsels of niet met het ongeval samenhangende aandoeningen.

In hoofdstuk XII tenslotte komt de femurschachtfractuur in een aantal combinaties ter sprake. Besproken worden de femurschachtfractuur en het homolaterale heupletsel, waarbij vooral wordt gewezen op het voorkomen van een dijbeenhals of een pertrochantere fractuur aan dezelfde zijde als de femurschachtfractuur. Het blijkt, dat deze proximale fractuur nogal eens over het hoofd wordt gezien. Dit kan ook het geval zijn bij een femurschachtfractuur en een laesie van het strekapparaat. De combinatie femurschachtfractuur en homolaterale onderbeenfractuur is niet zeldzaam. In de onderhavige serie deed de combinatie zich bij 11% van de patienten voor. Het waren allen patienten, die een verkeersongeval hadden gehad, waarbij steeds een auto was betrokken. De onderbeensfractuur was bij de patienten in de onderhavige serie in 75% van de gevallen een open fractuur. Het lijkt belangrijk, dat met het oog op de problemen bij de verpleging en de behandeling één der fracturen door een oefenstabiele osteosynthese min of meer wordt 'geëlimineerd'.

Een femurschachtfractuur en een letsel van de nervus ischiadicus is een vrij zeldzame, maar ernstige combinatie. Vaker komt een uitval van de nervus peroneus voor.

Vele oorzaken kunnen voor deze uitval worden aangewezen, zonder dat er duidelijk één speciale naar voren komt.

Een betrekkelijk zeldzame combinatie is een

femurschachtfractuur en een letsel van de arteria femoralis superficialis (1%). De gevolgen van het niet herkennen of het niet adequaat behandelen van zo'n vaatletsel zijn zeer ernstig: in de regel leidt het tot een amputatie. Bij de patienten in de onderhavige serie slaagde een reconstructie van de arterie steeds. Tegelijkertijd werd de femurschachtfractuur gefixeerd. Bij alle drie patienten kon het been worden behouden.

In een aparte paragraaf wordt ingegaan op de vetembolie, die nogal eens bij een patient met een femurschachtfractuur kan worden waargenomen. Moeilijkheden worden ondervonden bij het exact definiëren van het begrip 'vetembolie'. Dit maakt het moeilijk klinische studies te vergelijken. De diagnose 'vetembolie' bij de patienten in de onderhavige serie is gesteld op drie verschillende kriteria en wel: klinisch syndroom met petechiën, een zeer lage arteriële zuurstofspanning en/of het vinden van vet in de longen of elders in het lichaam bij obductie. Op grond van deze kriteria is bij ongeveer 11% van de patienten in de onderhavige serie een vetembolie vastgesteld. De patienten hadden in de regel een ernstig verkeersongeval doorgemaakt, hadden vele nevenletsels en werden in shock binnengebracht. Centraal in de behandeling lijkt staan het voorkómen, respectievelijk behandelen van shock en het registreren en corrigeren van een te lage arteriële zuurstofspanning.

Aan het einde van deze studie rijst de vraag: 'Wat is de beste behandeling voor de patient met een femurschachtfractuur?'. Deze vraag is in deze vorm niet te beantwoorden. Een patient met een femurschachtfractuur biedt een zo grote variatie aan pathologie, dat er van één behandelingsmethode geen sprake kan zijn.

Het lijkt het beste, patienten met een femurschachtfractuur te scheiden in patienten, die een verkeers- of een werkongeval doormaakten en patienten, die een ongeval thuis hadden. Bij de laatste categorie heeft men in de regel te maken met oudere mensen, in de regel van het vrouwelijk geslacht, met als enig letsel een gesloten femurschachtfractuur.

Bij de behandeling dient het accent in de eerste plaats te worden gelegd op de algemene toestand en de eventuele prae-existente ziekten. De behandeling dient in eerste instantie conservatief te zijn. Wanneer na enkele dagen blijkt, dat er geen contraïndicaties zijn tegen operatie en wanneer mag worden verwacht, dat de fractuur stabiel is te fixeren, dan is operatieve behandeling van de fractuur geïndiceerd. Alleen als werkelijke oefenstabiliteit kan worden bereikt lijkt operatieve behandeling voordelen te bieden. In de postoperatieve fase dient te worden gelet op preventie van een bronchopneumonie, decubitus en urineweginfecties. Dit geldt uiteraard eveneens bij de conservatieve behandelingsmethode.

Door aan de hierboven aangegeven regels vast te houden kan mogelijk het hoge percentage bejaarden, dat binnen een half jaar na een femurschachtfractuur overlijdt, (in deze serie 33%) worden gereduceerd.

In de groepen 'verkeers- en werkongevallen' overwegen patienten van het mannelijk geslacht. Bij deze patienten en dan vooral bij de verkeersslachtoffers vragen algemene nevenletsels vaak prioriteit. De initiële behandeling van de femurschachtfractuur is dan meestal conservatief met uitzondering van de patienten, bij wie een absolute operatie-indicatie bestaat. Hierop wordt verderop ingegaan. Het is essentieel, dat de initiële conservatieve behandeling vanaf het eerste moment optimaal wordt uitgevoerd. Het is fout een hoekstand of een aanzienlijke verkorting te accepteren met de gedachte deze bij een latere osteosynthese te corrigeren. Men weet immers bij deze categorie patienten nooit welke problemen en welke absolute contra-indicaties voor een osteosynthese zich nog zullen voordoen.

Bij de patienten uit de categorieën verkeer en werk, waar algemene nevenletsels niet op de voorgrond staan, moeten die patienten worden herkend, bij wie een absolute indicatie tot een osteosynthese van de femurschachtfractuur bestaat. Dit zijn de patienten met een femurschachtfractuur en

1. een homolateral heupluxatie
2. een letsel van de arteria femoralis superficialis
3. een letsel van de nervus ischiadicus
4. een letsel van het strekapparaat van de knie
5. een ernstig homolateraal knieletsel
6. een zeer uitgebreid weke delen letsel (b.v. avitaal spierweefsel, grote huiddefecten etc.).

Bij deze patienten bestaat er een indicatie tot onmiddellijke operatie ongeacht of de fractuur open of gesloten is. In de regel zal een osteosynthese met een AO-plaat worden uitgevoerd omdat deze procedure vrijwel altijd oefenstabiliteit biedt, ongeacht het fractuurtype.

Het risico van een vertraagde consolidatie

weegt op tegen de gunstige voorwaarden, die worden geschapen voor een zo goed mogelijk anatomisch en functioneel herstel.

De onder 6. genoemde absolute indicatie lijkt enigszins controversieel. Men vergroot immers door de operatie de hoeveelheid gedevitaliseerd weefsel. De situatie ligt bij deze letsels echter anders. Wil men een ongestoorde genezing van een ongevalswond bereiken, dan dient als onderdeel van het uitgebreide wondtoilet (dit kan b.v. huidtransplantaties inhouden) de fractuur te worden gestabiliseerd. Alleen zo kunnen de weke delen optimaal genezen en kunnen de resterende spiergroepen in een vroeg stadium worden geoefend, waardoor de schade, toegebracht bij het ongeval, beperkt kan worden gehouden.

Verschillende gegevens voortvloeiende uit deze studie wijzen erop, dat de conservatieve behandeling de initiële therapie der keuze is. Als de operatiekamerfaciliteiten, wat betreft asepsis, anaesthesie en personeel bijzonder gunstig zijn, kan een uitzondering worden gemaakt voor gesloten fracturen, die samengaan met een homolaterale acetabulumfractuur, een dijbeenhalsfractuur, een homolaterale patellafractuur of een homolaterale onderbeenfractuur. Alleen wanneer aan strikte voorwaarden voor een veilige osteosynthese kan worden voldaan, is osteosynthese à chaud op grond van bovengenoemde relatieve indicaties verantwoord. In principe echter en zeker bij open fracturen verdient als initiële behandeling de conservatieve behandeling de voorkeur. Wederom geldt bij deze conservatieve behandeling dat dient te worden gestreefd naar een zo goed mogelijke repositie van de fractuurstukken vanaf het allereerste moment. Bij verdenking op interpositie of bij een persisterende asafwijking dient een repositiepoging in narcose te worden ondernomen.

In de tweede week na het ongeval moeten die patienten, die in aanmerking komen voor electieve osteosynthese worden geselecteerd. De door het ongeval in gang gezette pathofysiologie is in de tweede week over zijn hoogtepunt heen en de dreiging van een vetembolie is vrijwel voorbij. Het is nu de kunst in deze periode die patienten uit te zoeken, die kunnen profiteren van een operatieve behandeling van hun femurschachtfractuur.

Volgt hieruit dat de conservatieve behandeling een minder goede behandeling is?

Hoewel de conservatieve behandeling een veilige behandelingsmethode is, die in de regel een bevredigend en redelijk resultaat geeft, gaat deze toch wel met een erg lange opnameduur gepaard. Heden ten dage staan er osteosynthesetechnieken ter beschikking, die de opnameduur significant kunnen bekorten en die meer garantie bieden voor een volledig anatomisch en functioneel herstel dan de conservatieve behandelingsmethode.

De patienten, die bij voorkeur operatief zullen worden behandeld, zijn die patienten, die een buigingsfractuur hebben, die oefenstabiel kan worden gefixeerd en dan bij voorkeur met een Küntscherpenosteosynthese *met* opboren van de mergholte. De resultaten van deze techniek bleken in de onderhavige studie voortreffelijk te zijn, zij het dat er zich een te groot percentage rotatiefouten voordeed. Deze kunnen echter worden toegeschreven aan de toegepaste techniek van het gesloten reponeren en het lijkt mogelijk deze fout tegen te gaan door open repositie toe te passen. De Küntscherpenosteosynthese *zonder* opboren van de mergholte dient als routinebehandeling niet meer te worden toegepast. Het indicatiegebied is te klein (in casu dwarse fracturen juist in de isthmus) en het aantal complicaties is, althans in de onderhavige serie, te groot. De AO-plaatosteosynthese heeft een groter toepassingsgebied dan de Küntscherpenosteosynthese *met* opboren van de mergholte. Comminutieve fracturen, buigingsfracturen met een groot driehoekig fragment en spiraalfracturen kunnen alle met deze techniek oefenstabiel worden verzorgd. Een vrijwel volledig anatomisch en functioneel herstel is verzekerd, tenzij een diepe infectie optreedt. De gevolgen van zo'n diepe infectie zijn ook bij adequate behandeling zeer ernstig.

Wanneer het mogelijk is zodanige maatregelen te treffen, dat de kans op het optreden van zo'n diepe infectie wordt gereduceerd, dan betekent deze methode van de AO-compressieplaat een uitgesproken aanwinst. Tenslotte, moet thans in 1973 de conclusie van Dencker uit 1963 luidende: 'De conservatieve behandeling is de beste routinebehandeling voor een femurschachtfractuur' worden herzien?

Het antwoord op deze vraag moet bevestigend zijn.

In de Küntscherpenosteosynthese *met* opboren van de mergholte en met enig voorbehoud ook in de AO-compressieplaat staan nieuwe osteosynthesetechnieken ter beschikking, die bij optimale uitvoering voor het merendeel van de patienten met een femurschachtfractuur een duidelijke winst met zich brengen.

Checklist

Checklist for initial check-up of patients with a fracture of the femoral shaft, as it is in use at the Groningen University Hospital. It has to be stated that this list does not replace the standard routine physical examination; it is merely meant as a supplementary memory-support.

- control of respiration and circulation
  - pulse rate, periferal circulation
  - blood pressure
  - nasogastric tube
  - intubation or Mayo-tube

  } in coma or chest injury patients
- undress patient completely
- auto-anamnesis (especially: the way the accident happened; pre-existent diseases)
- hetero-anamnesis (especially: steroids, anticoagluant drugs, antihypertensive drugs)
- venous blood sample
  - ABO and Rh
  - urea and creatinine
  - liver function tests
  - Na, K, Chl. Ca and Ph
- insertion of an intravenous line
- arterial blood sample (PO_2, PCO_2, pH)
- haemoglobine, platelets
- status generalis
- status localis
  - skin, wounds
  - distal arterial pulsations
  - nerve function
- (re)splinting
- X-ray
  - femur, ap. and lat.
  - pelvis
  - knee
  - ankle
  - chest
- E.C.G. in all patients above age 45
- homolateral associated injuries:
  - ☐ hip dislocation
  - ☐ fracture femoral neck
  - ☐ fracture trochanteric section
  - ☐ fracture femoral condyles
  - ☐ rupture quadriceps tendon
  - ☐ fracture patella
  - ☐ rupture ligamentum patellae
  - ☐ fracture tibial plateau
  - ☐ fracture lower leg
  - ☐ fracture ankle